EVERYDAY BIOLOGY

CURRICULUM

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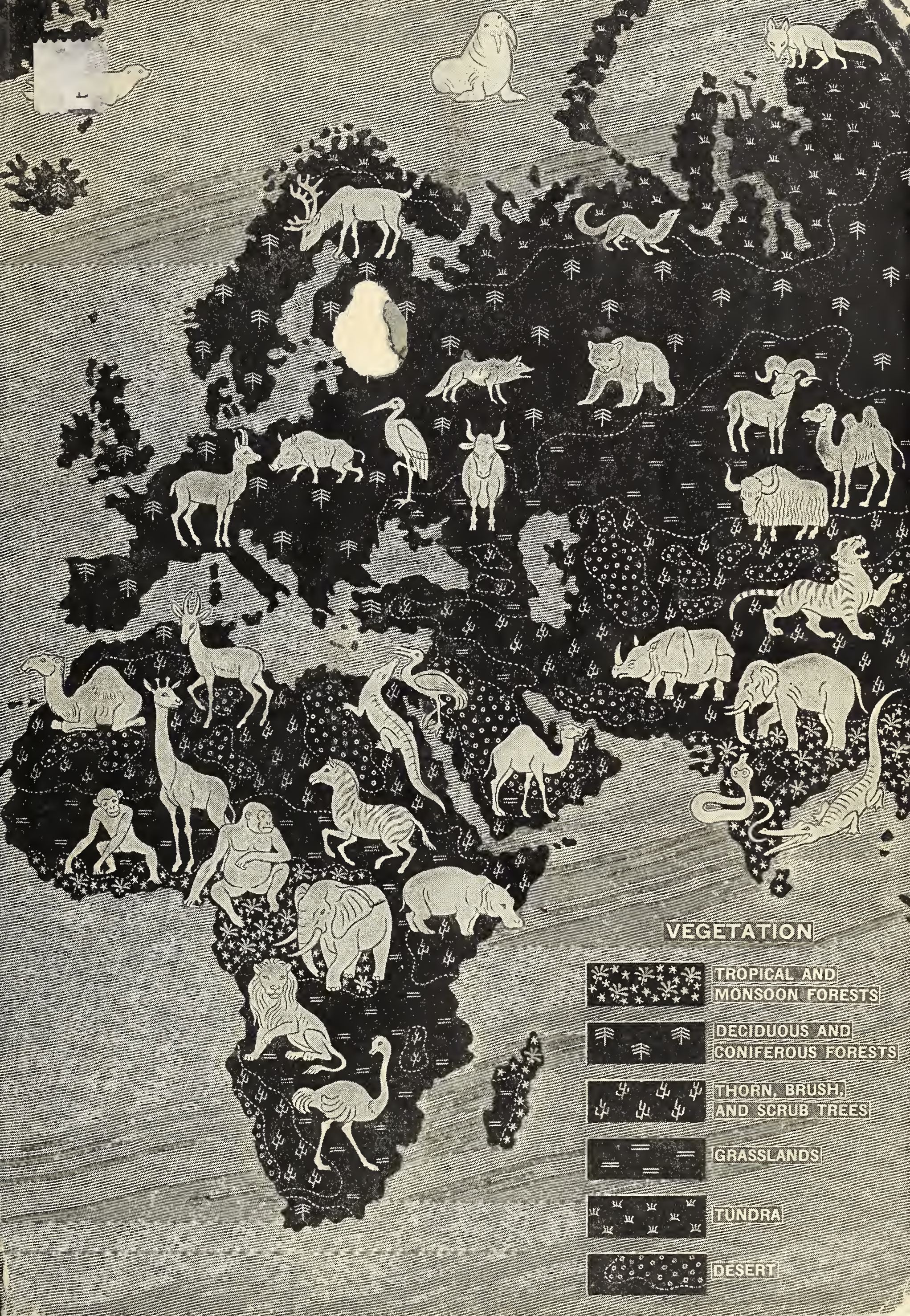
VEGETATION
TROPICAL AND MONSOON FORESTS
DECIDUOUS AND CONIFEROUS FORESTS
THORN, BRUSH, AND SCRUB TREES
GRASSLANDS
TUNDRA
DESERT

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EVERYDAY BIOLOGY

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PREFACE

This book presents a simple and logical organization of materials which cover the scope of elementary biology. The subject is constantly related to common experiences and to the interests of pupils in everyday activities. Emphasis is given to the social aspects of biology, especially to such important interpretive understandings as health, conservation, and recreation. In short, this book is planned to teach the kinds of biological science which everybody needs to know.

The general organization presented herein has grown out of many years of careful study and trial with high-school classes in biology. The learning activities were selected and refined through repeated classroom use. The book is the cumulative result of years of co-operation with teachers and students of biology. *Everyday Biology* has been developed from the authors' earlier *Biology for Today*; in addition to the distinctive elements of that book, it presents new features which have been proved to have important practical values in the classroom.

Guidance in the selection of specific content was secured through extensive research by the authors[1] and other investigators. Topics thus shown to have greatest importance are designated by asterisks. These topics, therefore, are the most important ones to be included in the minimal essentials of any plan of instruction which the biology teacher may use.

Eight units are included, each one presenting a major phase of biology. These units are preceded by an introductory chapter, and are followed by a section of directions for various biological activities which the authors' experience has shown to be effective in the development of leisure pursuits and hobby interests. The eight units are made up of twenty-nine chapters, all of which are developed from the standpoint of functional biology.

Special care has been taken, in harmony with the most authoritative suggestions and recommendations,[2] to achieve the major aims of science-teaching, which are (1) to develop an understanding of the fundamental generalizations, or principles, of biology to the end that these may contribute optimally

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[1] Otis W. Caldwell and Florence Weller, "High School Biology Content as Judged by Thirty College Biologists," *School Science and Mathematics*, Vol. XXXII (April, 1932), pp. 411–424.

Francis D. Curtis, *A Synthesis and Evaluation of Subject-Matter Topics in Biology* (unpublished study).

[2] The Thirty-first Yearbook of the National Society for the Study of Education, Part I, *A Program for Teaching Science.* Public School Publishing Company, Bloomington, Illinois, 1932.

Science in General Education, the Report of the Committee on Science Instruction of the Progressive Education Association. D. Appleton-Century Company, Inc., New York, 1938.

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to the development of broad interpretive understandings, such as health, conservation, and the like; (2) to provide practice and facility in the use of scientific method; (3) to develop scientific attitudes. To this end many exercises on scientific attitudes, scientific principles, and scientific method are included in experiments, in legends of illustrations, and in special exercises at the ends of chapters.

The ability of the pupil readily to comprehend a textbook depends chiefly on two factors: simplicity of vocabulary and simplicity and clarity of style. Guided by the results of extensive research conducted over a period of years, the authors have limited the nonscientific vocabulary chiefly to the seven thousand words most frequently used, as presented in Thorndike's list of "Twenty Thousand Words." When other words are used, each is defined and pronounced, as are also certain words of the seven-thousand-word level which are not likely to be readily comprehended. The essential scientific vocabulary has also been determined by research.[1] Scientific terms are defined in the body of the text and also in the Glossary. Such terms are repeated at the ends of chapters, as well as at several points in context, in order to provide the necessary drill in their use.

To ensure ready comprehension of the materials by pupils of all levels of ability, the authors have employed chiefly short simple sentences and short paragraphs. Moreover, as a check upon ease of comprehension by pupils, the completed manuscript was submitted to high-school pupils who were about to begin their study of biology. All passages which any of these pupils found difficult were revised until the reader experiencing the difficulty pronounced them to be entirely clear. The manuscript was also read critically for ease of comprehension by adults who had no special training in biology.

Self-tests on the comprehension of essential subject matter are distributed at frequent and convenient points in the various chapters. More extensive tests are also provided, not only of subject-matter comprehension, but also of understanding of scientific principles and of ability to use the elements of scientific method and to react in terms of scientific attitudes.[2]

This book provides abundantly for laboratory work, including all the experiments generally considered essential to the course in biology for secondary schools. These experiments and many additional ones are presented, together with a wide variety of additional activities and aids to learning, in the Workbook.[3]

[1] Francis D. Curtis, *Investigations of Vocabulary in Textbooks of Science for Secondary Schools.* Ginn and Company, Boston, 1938.

[2] *Tests to Accompany Everyday Biology.*

[3] *Workbook to Accompany Everyday Biology*, by Francis D. Curtis and Nina H. Sherman.

Materials of special interest and value to the teacher are provided in the *Teachers' Manual and Key to Accompany Everyday Biology.*

Abundant provision for individual differences will be found in the wide variety and large number of problems and activities which are presented in the legends of illustrations, at the ends of chapters,[1] and in the section on "Biology for Leisure Time"; in experiments and projects; and in scientific terms in parentheses at various points in the text and in the illustrations.[2]

The content of this book has been carefully checked against a large number of representative state and city syllabi and will be found to include the materials required in those syllabi.

THE AUTHORS

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[1] These questions, together with the "Self-tests" and the various other activities at the ends of chapters and units, are discussed in the *Teachers' Manual and Key to Accompany Everyday Biology.*

[2] These terms are not intended to be considered as minimal essentials to be learned by all members of the class. They are included for pupils who may wish to learn and to use a more extensive biological vocabulary than that which is presented as fundamental.

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TO THE STUDENT

HOW TO STUDY

The materials in this book are organized into a few large units in order to help you in learning to think of biology in terms of its largest ideas and principles. Your problem is somewhat like that of a pioneer in a strange country. He climbs a hill or a tree in order to get a general idea of the surrounding country and to locate the principal landmarks. In the same way your first need is to get a general idea of each unit as you begin its study and to learn what are its chief problems. Turn through the unit, noting the titles of the chapters. Then in the first chapter of the unit read "Questions This Chapter Answers." Note which ones you think you can answer completely, which partly, and which not at all. Similarly, examine the other chapters of the unit. Having gained a good general idea of what the unit discusses, you are now ready to take up the study of the assignment.

1. First read the entire assignment through rapidly. Then, with its main points in mind, read the assignment again carefully, paragraph by paragraph, for an accurate and detailed knowledge of what it contains. Train yourself to get the essential ideas and facts out of each paragraph with only this second reading. There should be little or no difference between reading a text and studying it.

2. In your second reading, read carefully; then close the book and try to state to yourself the most important ideas in the paragraph or paragraphs you have just read. It is not desirable to try to remember or to repeat the exact words of the book. It is far better to remember the ideas which are presented and to restate these in your own words. At first you may not be able to do this with a single careful reading, though you should learn to do this. You can train yourself to master a short section in a single careful reading.

3. As you read a paragraph, try to find a key sentence, that is, one sentence which indicates better than any other in that paragraph what the whole paragraph is about. Often this sentence will be the first one in the paragraph, as is the case with the first and third paragraphs of Chapter I. Sometimes the key sentence is the last one, as, for example, in the second paragraph of Chapter I. If the book is your own, it is good practice to draw a line under each key sentence. Having the key sentences thus marked will be of great help to you both in fixing the ideas in mind and later in reviewing the materials.

4. After you have read a paragraph, close the book and try to make a summary in a single sentence of the most important thought of the paragraph. Of course the length of this sentence will vary with the material and length of the paragraph; but twenty words is a convenient limit, and sentences with fewer words are often better. For example, the third paragraph in Chapter I, beginning with "Biology is an important part of practically every aspect of modern life," can be summarized by this sentence: "Biology is important in practically everything that everybody does or experiences."

5. After you have read a paragraph, write a few questions the answers to which you think are important and which you think any student who has read the same paragraph should be able to answer. Try to make these questions test the application of facts rather than the mere recall of the facts themselves. Under the illustrations and at the ends of the chapters are many questions of this sort.

6. The illustrations are intended to assist you in studying the text. Therefore always study an illustration at the point where it is referred to in the text. Only in this way can you get the most benefit from the illustrations. Additional facts or questions are included in most of the legends under the illustrations. Try to answer these questions.

7. Students are often unable to give a good discussion of a topic. Sometimes when asked to discuss, the student merely tells everything he can remember about the topic, giving the facts in a disconnected way as they occur to him. You can train yourself to make good discussions by learning to follow this simple outline of questions, answering each as you come to it:

What is it? (Make a definition or a short description of the object or process you are discussing.)
What is its history (if its history is important)?
What is its habitat; that is, where is it found? Or where does it occur?
What are its most important characteristics—those which distinguish it from everything else?
What can it do?
What is its relation, if any, to man?

Not every topic, of course, will entirely fit this outline. Omit the questions which are not appropriate.

8. Comparing one animal, plant, process, or law with another is a valuable way of learning and remembering important facts and principles. A good comparison includes both the respects in which things are alike and the

respects in which they are different. Therefore write first all the similar characteristics of the two organisms, biological processes, or whatever you are comparing. In a separate column write all the respects in which they are different. Then select from the two columns the points which you think are of most importance.

9. The successful student usually reviews his material frequently and thoroughly. At the ends of the problems within the chapters are tests which will aid you not only in testing yourself to see whether you have mastered the materials but also in reviewing the materials. *Do not write the answers to the test questions in your book*, since such practice will rob them of most of their value for later reviews, when you will want to test your memory and re-read parts which you may have forgotten.

10. After you have completed the study of a chapter, turn again to "Questions This Chapter Answers." If you cannot now answer all these questions, review the chapter until you can. In the same way test your understanding of each chapter of the unit.

After you have completed the study of any unit, change into a complete statement each of the "Questions This Chapter Answers." Then, using these statements as major headings, write under each, in your notebook or in the Workbook at the place indicated, complete statements which further explain or give proof of each problem presented. You may be able also to organize the problems and your statements in the form of an outline.

11. In making a comparison or a discussion, in reviewing, or in summarizing a unit, use any knowledge or experience you have had, whether gained in school or out of school.

Outdoor recreation promotes health and hence is closely related to biology

CHAPTER I

Biology, the Study of Life

Of what importance is biology? Less than a hundred years after Columbus discovered America, a demand arose for a canal across the neck of land which connects North America and South America. Finally, about sixty years ago, a company from France started to build the Panama Canal. But the French company failed to complete its task. An important reason for the failure was that so many of the workmen became sick with yellow fever or died from that terrible disease.

Later the United States took over the task of building the canal. Those in charge of the work knew, however, that, before they could accomplish their purpose, they must first conquer yellow fever. This was a task for the biologist,[1] not for the engineer. The story of the conquest of yellow fever is one of the most fascinating stories in history. Biological[1] science won, and the Panama Canal was completed.

Biology is an important part of practically every aspect of modern life. Either directly or indirectly all the activities of nations and of individuals are related to biology. A few examples will make these statements clear. After a flooding river has covered farms and cities, the most important problems which arise have to do with biology. A journey of exploration into the polar regions or into the jungles can be successful only if the biological aspects of the undertaking have been carefully considered beforehand. The successful operation of great railroad, steamship, and airplane lines depends to a considerable extent on the application of biological knowledge. A football team can be successful only if its members know and obey certain laws of biology. It would be possible to make very long lists of examples such as these, which suggest the importance of biology in modern life.

Biology is not a modern, or new, branch of learning. It is the most ancient of all studies. Thousands of years before anybody ever thought of algebra, history, or English, ancient man was studying nature. His life depended on accurate knowledge of the living things about him. He had to observe and study the habits of animals in order to know which were harmless, which he could capture or successfully fight, and which he must avoid because they

To the Teacher. Suggestions which may be of value in the use of illustrations will be found in the *Teachers' Manual* to accompany this book.

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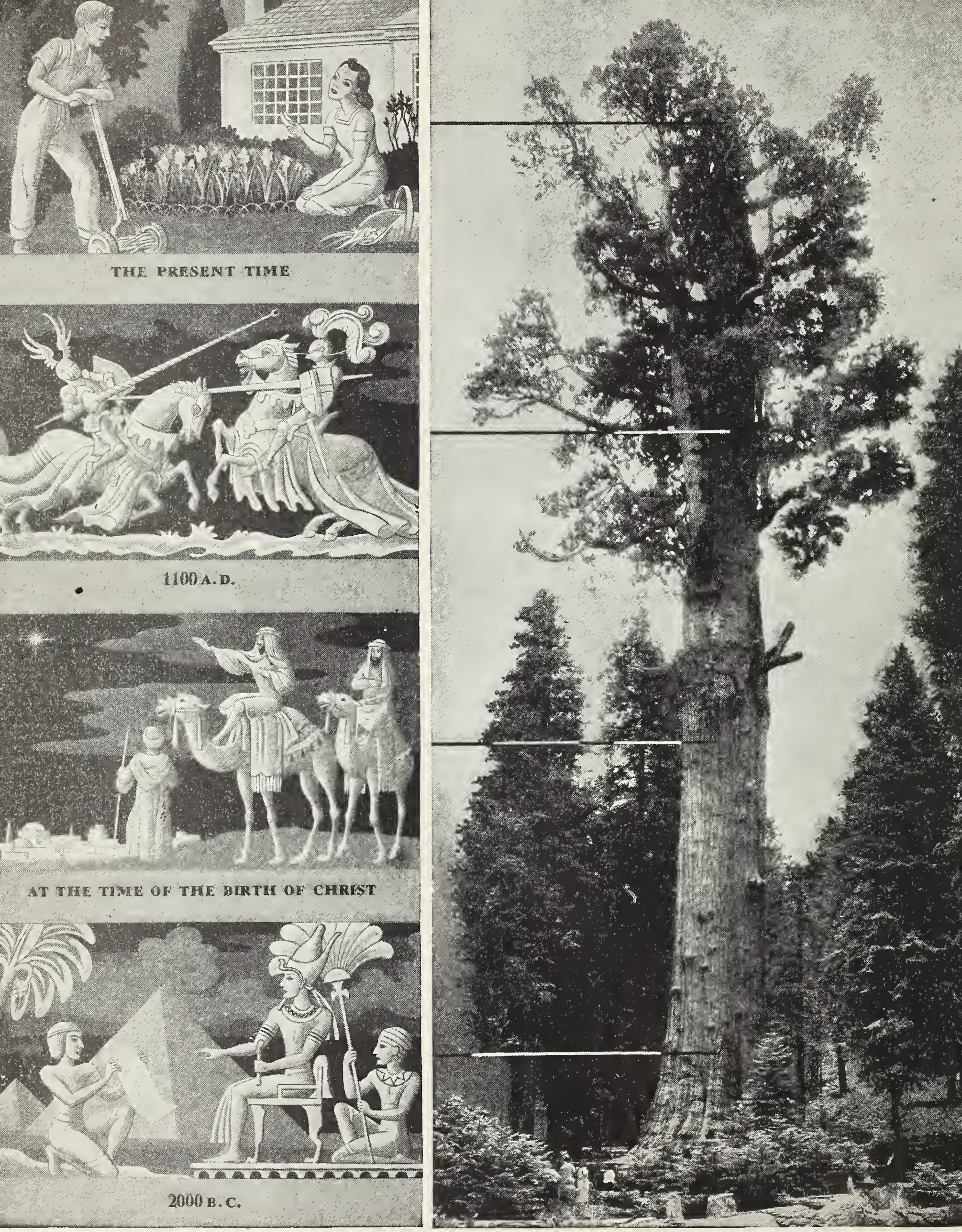
[1] *Biologist* (bī ŏl′ō jĭst): one who makes a special study of plants and animals. *Biological* (bī ō lŏj′ĭ kl): having to do with biology.

Most of the pronunciation symbols that are used throughout the book are self-explanatory. The values of the following symbols are briefly indicated: āle, ădd, ärm, ȧsk, sofȧ, ēve, ĕnd, maker, īce, ĭll, ōld, ôrb, ŏdd, cūbe, ûrge, ŭp, fo͞od, fo͝ot.


THE PRESENT TIME
1100 A.D.
AT THE TIME OF THE BIRTH OF CHRIST
2000 B.C.

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The General Sherman sequoia, in Sequoia National Park, California. This tree has been living throughout much of human history. It was a sturdy young tree at the time of the ancient Egyptian empire; today it is the largest living thing. It is estimated to be more than four thousand years old. About what fraction of its life is represented by all the time since Columbus's first voyage to America?

might harm or even kill him. He had to know which fruits, leaves, and roots he could eat, and which were unpleasant to the taste or were poisonous. This knowledge was biology of a crude and practical sort; yet it was probably the kind of knowledge that ancient man needed most.

A knowledge of biology and the uses of such knowledge are necessary now, and have been equally so in the past. Moreover, as our ways of civilized living become more complex, there is an increasing need for a broader and deeper knowledge of biology.

What is biology? *[1]Biology is the study of living things. The word *biology* is derived from two Greek words which together mean "the science of life."

Biology deals with all plants and all animals of whatever kinds they may be.[2] It is evident, therefore, that biology is indeed an extensive study. There are more than a million different kinds of animals and plants now living. These differ from one another greatly and in many ways. For example, the largest living things are the sequoia trees in Sequoia National Park, California. Certain seaweeds, the longest plants known, may reach six hundred feet in length. In contrast, there are some living things that are so small that they cannot be seen, even with the most powerful microscopes yet invented.

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[1] To the Teacher. The paragraphs marked with an asterisk contain the materials which extensive research has indicated as being of major importance (see Preface). Suggestions for the effective use of this material will be found in the *Teachers' Manual.*

[2] There are many divisions of biological study—for example:

Anatomy, study of the details of the structure of plants and animals.
Bacteriology, study of bacteria, how they live and how they affect other things.
Botany, study of plants.
Cytology, study of the details of cells and protoplasm.
Ecology, study of the relations of plants and animals to their environment.
Embryology, study of the earliest stages in the development of plants and animals.
Genetics, study of the heredity of plants and animals.
Hygiene, study of ways of preserving health.
Morphology, study of the forms and parts of plants and animals.
Paleontology, study of fossil records of plants and animals.
Pathology, study of diseases in plants and animals.
Physiology, study of the life processes, such as digestion, circulation, and the like, of plants and animals.
Sanitation, study of ways of securing and maintaining healthful living conditions.
Taxonomy, study of the classification and naming of plants and animals.
Zoology, study of animals.

The letters *ist*, usually in place of the last letter of each of these words, change the word into the name of the kind of scientist who makes a special study of that branch of science. Thus a botan*ist* is a scientist who studies *botany*, a zoolog*ist* is a scientist who studies *zoology*, and so on.

A. M. N. H.

The saber-toothed tiger. This animal lived many centuries ago in various parts of North America. It has long been extinct. How do you think that scientists have been able to learn how it looked?

The oldest living things are trees. The baobab trees of Cape Verde, for example, are believed to be more than five thousand years old, and certain cypress trees of Mexico are perhaps still older. Some of the simplest plants, however, live their entire lives in less than an hour.

What does biology include? The apple is one of the earliest known fruits. Two varieties of apples were known to the people of the Stone Age. There are now several hundred varieties. All these were developed from a species of wild apple tree with fruit less than an inch in diameter. That kind of tree is still found growing wild in central and southern Europe. All the improved fruits and vegetables which are so important a part of our food were developed from less desirable fruits and plants. The science of producing improved varieties of plants and animals is one part of applied biology.

Skulls of ancient men have been found upon which surgical[1] operations had been performed with crude stone tools. Circular pieces of the bone had actually been removed from the heads of living men without causing death, as is shown by the fact that the wounds had healed. New bone had grown over the places where the cuts had been made. In one case the operation was performed five times upon the same person; yet he died later of some cause other than the operations. It is believed that these operations were performed in an effort to cure illnesses. The treatment of disease and the improvement of health have made giant strides since the time of these crude attempts at surgery. All that is now known in the fields of medicine and hygiene is applied biology.

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[1] *Surgical* (sûr'jĭ kl): having to do with surgery. *Surgery* (sûr'jẽr ĭ): the branch of medicine which includes the performing of all operations on living bodies.

Leeuwenhoek observing an object through a microscope of his own manufacture. **Special Report:** The scientific work of Leeuwenhoek

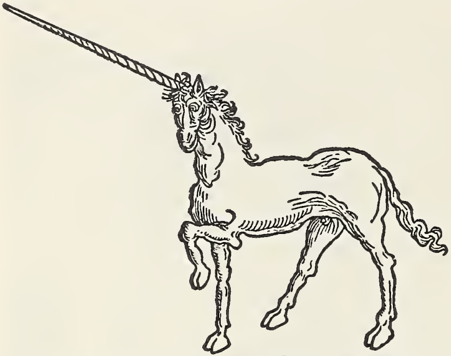
Every year fires destroy thousands of acres of valuable and beautiful forests. Floods sometimes wash away the soil needed for food crops. In recent years severe dust storms have caused great damage in several states. The problems of conservation arising as a result of forest fires, floods, and dust storms make up another aspect of biology.

The development of cities has produced many new biological problems. Many of these have been solved through the application of science. For example, until fairly recent times, cities had no satisfactory ways of securing enough good water or of disposing of sewage and garbage. Some ancient cities were buried in their own refuse and by dust and sand, and, later, new cities were built on top of older ones. The science of sanitation, which makes our modern cities and dwellings clean and healthful places in which to live, is merely applied biology.

All the animals and plants now living are but a small part of all those which have lived since the time when life first began on the earth. Countless kinds of plants and animals, many of them similar to those now found on the earth and others quite different, existed for a while and then became extinct. But all the organisms[1] that have ever lived on the earth have had

[1] See the Glossary.

to meet and solve many problems of living. Some of these problems are common to all. Others concern or have concerned only individual organisms. The study of the ways in which all living things meet their life problems is included in biology.



Pierpont Morgan Library

A drawing of a unicorn copied from a book published in 1486. Even scientists of that time believed that unicorns existed. What scientific attitudes did those scientists not have?

Biological materials may be found almost everywhere. They are constantly to be found both inside and outside of our homes. In our dwellings we may be troubled by ants, clothes moths, or other insects, food may spoil, or we may have many other biological problems. In a vacant lot or in a park one may find among the weeds grasshoppers, crickets, beetles, perhaps a garter snake, a toad and seeds and fruits of plants. These are also a part of biology.

Biology and daily living. *Biology is a practical study. The person who has a knowledge of biology finds many uses for this knowledge. Biology will prove most valuable to you if by your study of it you learn to know and to apply scientific method and scientific principles, and if you develop scientific attitudes.

*All scientific knowledge is gained through the use of scientific method. Scientific method begins with accurate observation. It includes finding problems, planning and carrying out experiments, and other activities which are listed on page 625 of this book. You will have many opportunities to practice the use of scientific method in the pages that follow.

*Scientific method is something which one can use outside as well as inside the science classes. It is a method which can be used every day in almost every situation. Thus the doctor uses scientific method in deciding what to do in order to cure the sick and the injured. The housewife may learn to cook, or she may discover how to improve her cooking, by applying scientific method. A boy may learn to catch more and bigger fish than other fishermen, or a girl may learn to swim or to play tennis better, by using scientific method. One may improve one's skill in driving, or one may grow fine vegetables and flowers, by knowing and using scientific method. Hundreds of uses of scientific method, such as these, might be stated.

From the facts presented in these pictures, and from the knowledge that all these fruits grow on trees, you might state the minor principle "Some animals eat foods that grow on trees." From just the facts shown here you would not be able to state as a major principle, "All animals eat foods that grow on trees." Explain why. Can you state any other minor principle which these pictures suggest?

*The scientific attitudes are closely related to scientific method and are just as important and useful in everyday life. Thus everybody should acquire the attitude of respect for other people's opinions. Everybody should try to free himself from superstitions. Everybody should cultivate the attitude of considering carefully what he hears and of not "jumping at" conclusions. The pages that follow contain many exercises which will help you to acquire the scientific attitudes listed on page 624 of this book.

*Everybody who studies biology should gain an understanding of biological principles. A principle is a statement that sums up many related facts. To illustrate, suppose that you were to make a flower garden. Suppose that you observed for the first time that seeds developed from nasturtium flowers, and later that seeds developed also from sweet peas, roses, irises, and every other flower in your garden. You could then put all these separate facts which you had observed about the forming of these seeds into one statement: "The seeds of many flowering plants develop from flowers." This statement is a principle because it sums up many separate but related facts.

Again, suppose that you were to see a frightened cat jump into the water and swim away from danger. Suppose later that you saw a pig swimming across a river. Suppose also that you saw a chicken fall into the water and begin at once to swim ashore. You would probably already have observed dogs, geese, swans, and ducks swimming about. You might then put all these separate observations together to form such a principle as this: "Many animals can swim."

*Such a statement as this and the one about flowering plants in the preceding paragraph are minor principles because it is evident from the way in which they are stated that they are based on relatively few observations. When, however, such statements are general, that is, true of all plants or of all animals, they are major principles.

In the chapters that follow you will have opportunities to build an understanding of many principles from your observations, experiences, and study. You will learn to use your knowledge of principles outside as well as in school.

ADDITIONAL EXERCISES AND ACTIVITIES

Self-test on Biological Principles. One frequently hears the statement "Survival is the first law of life." It means that the most important problem of every organism is the problem of keeping alive. Do you think this statement is true? Explain.

Exercises on Scientific Attitudes. 1. Which of the scientific attitudes listed on page 624 were used by primitive men?

2. Which of the scientific attitudes tend to prevent (1) gossip; (2) slander; (3) belief in advertising claims in general; (4) belief that everything that is printed is true; (5) wearing "good-luck rings"; (6) belief in ghost stories; (7) exaggeration, or overstatement?

3. One frequently hears the statement "Today's truth may prove to be tomorrow's abandoned hypothesis" (see the Glossary). To which one of the scientific attitudes does this statement refer?

Self-test on Important Biological Terms. Explain in your own words each of the terms in this list. Consult the Glossary for definitions of biological terms.

biologist
biology
botany
organism
physiology
zoology

Reference Books[1]

Caldwell, O. W., and Lundeen, G. A. *Do You Believe It?* Doubleday, Doran & Company, Inc., New York.

Ditmars, R. L. *Making of a Scientist.* The Macmillan Company, New York.

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[1] These are only two of many books that might be named because they furnish interesting and valuable information which supplements the material of this chapter but which is not found in biological textbooks written for use in high schools. Similar lists will be found at the end of each of the units that follow. A list of biological books to read for pleasure is found on page 650.

VACATION-TIME BIOLOGY

We found the strings of toad eggs in the spring shortly after they had been laid. Thousands of them were attached to sticks and stones in the relatively quiet water near the edge of the stream.

We watched them develop into tiny wiggling tadpoles, so numerous that they formed a black patch on the stream bottom. We found eight similar black patches within a half-mile of the first. What thousands of toads there would be later, we thought! But we were to learn much before the summer ended.

The tadpoles grew in size, until the black mass on the stream bottom covered about two square yards. But soon we noted that the patch was getting smaller. What was happening to the tadpoles? Where were they going? We watched to see. We saw that many in hurrying away from moving objects on the bank, which might be enemies, got into the swifter current and were swept down into the deep holes, where no doubt they were devoured by fish. Others were trampled by the cattle which came to drink. Hundreds of others were devoured by garter snakes which came daily to gorge themselves upon this easily captured prey. No wonder the black patch of tadpoles was visibly shrinking, almost from day to day.

Finally in late July the tadpoles that were left had developed into toads the size of a small kernel of corn and had begun to leave the water for the gravel bar. Here they were met by a flock of chickens which, in spite of the fact that the color of the toads matched that of the gravel, picked them up by dozens when they hopped. Not many survivors, it seemed, would succeed in reaching the grass beyond the gravel bar. There were snakes, we knew, in that grass, and crows in the near-by fields. Later we found dozens of small toads which had been killed by automobiles while crossing the road close by. Certainly there would be few to lay their eggs in the stream next spring. Now we knew why toads need to have many offspring in order to survive.

How many enemies of the toad can you name?

UNIT I · SOME MAJOR PROBLEMS

During a walk through the woods we may see a black snake in the act of swallowing a garter snake, a squirrel searching a pine cone for seeds, a dwarfed tree under a vigorous large tree, a large number of good-sized evergreens all dead, with no apparent reason for their having died, a whole hillside black and ugly as the result of a forest fire, a woodpecker busily hammering on the trunk of a tree, and a handful of feathers beneath an empty nest.

While strolling along the seashore we are sure to see many empty and broken shells of ocean animals and much dead and dry seaweed left by the tide. These are the remains

WHICH LIVING THINGS MUST SOLVE

of plants and animals which have been unsuccessful in the battle to keep alive. We may see a gull drop a clam from a considerable height upon the rocks in order to break its shell, only to have the clam snatched up by another gull before the original finder can reach it. We may see a small and twisted tree lifting its remaining leaves above the sand which is slowly burying it, or we may see another tree barely managing to exist on the top of an off-shore rock.

Such sights as these are signs of the struggle for existence in which all living things are constantly engaged. This unit will discuss various aspects of this struggle.

CHAPTER II

Conditions Affecting Life

Questions This Chapter Answers. In what sense is each of the following conditions a factor which makes life possible or which limits life: food, heat, oxygen, water, light, carbon dioxide, shelter, land formations and bodies of water, weather and climate, soil, relations among living things, and changes in the environment, or surroundings?

WHAT FACTORS OF THE ENVIRONMENT ARE ESSENTIAL TO ALL LIVING THINGS?

Environment and life. When the great explorers Byrd, Peary, Amundsen, and Scott made their famous expeditions into the forbidding polar regions, they carried with them the food which the men and dogs would require during the long months of their stay. They knew that they would not find there plants and animals which would serve for food. Where Byrd made his main camp, on the icy shore of the Antarctic Ocean, there were, it is true, a few animals, such as seals and penguins, and in the arctic regions in general there are polar bears, walruses, and seals. But on the great wastes of ice and snow at the north and south poles there are no visible living things.

Contrast the barren snow and ice deserts of the north pole and the south pole with the jungles of the equator. In the moist tropics life is more abundant than in any other part of the world. If all the organisms living in one square mile of jungle could be found and classified,[1] the number of different kinds would doubtless run into thousands.

Why is it that life is abundant in some parts of the earth, while it scarcely exists at all in others? The reason is that life can exist only under certain conditions of the environment, or habitat.[2] Certain of these conditions, or factors, are necessary to all living things. Others are necessary to most living things. Some are necessary in indirect ways. Not only are these factors essential to life, but the degree in which they are present regulates the numbers and kinds of plants and animals which may exist in various regions.

Food. *Every living thing must secure energy[3] in the form of food. Scarcity or abundance of food is one of the chief factors affecting the num-

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[1] *Classify* (klăs'ĭ fī): to put things into groups, or classes, according to qualities in respect to which they are similar. *Classification* (klăs ĭ fĭ kā'shŭn): the act of classifying or the result of classifying.

[2] See the Glossary.

[3] *Energy* (ĕn'ẽr jĭ): the capacity to do work. Anything has energy if it can move or cause something else to move. Some of the common forms of energy are heat, light, electricity, chemical energy (such as the energy stored in food), and mechanical energy (the energy of movement).

Galloway

Eskimos eating crabs. What biological problems do these people need to solve in order to remain alive and comfortable?

bers and kinds of plants and animals. It is not uncommon to find land upon which trees, crops, flowers, and even grass will not grow. Such land is called "poor soil." This term usually means that the soil does not contain certain substances which plants need. An abundance of food often causes an enormous increase in the number of animals and plants. An insufficient[1] supply of food causes a corresponding decrease because the weaker ones, especially, die in great numbers. Wars are followed by the disaster of famine or near famine in large areas.

Many animals can live for relatively long periods without food. There are on record cases in which people have fasted for several weeks without apparently suffering permanent ill effects. Horned toads and alligators can live for several months without eating, and certain insects have been observed to live for several years without food. During such periods food previously stored within the body is consumed.

Heat. Heat energy is necessary to all plants and animals. An experiment will show how heat is related to the development of plants from seeds.

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[1] *Un, dis, non,* often *in,* or occasionally *im* at the beginning of a word gives the word the opposite meaning from the one it would have without this beginning syllable.

Experiment 1.[1] Do the amounts of heat which seeds receive affect their germination?[2] Fill three flowerpots with sawdust, and plant in each a few bean seeds, corn grains, or other seeds. Moisten thoroughly. Put one pot in a very cold place—for example, out of doors in cold weather or in a refrigerator; place the second near a radiator or stove where the temperature most of the time is about 95° F; put the third in a room where the temperature is about 70° F. Keep the seeds moist and examine them after four days. In which of the pots have the seeds started to grow? In which pot do they grow best?

Can you plan a check experiment[3] which will show whether or not water must be present for seeds to germinate?

*Various organisms differ greatly in the temperature at which they can live. Certain of the lower plants, such as algae, can carry on their life activities at temperatures above that of boiling water. In contrast, certain bacteria which cause food to spoil have been known to remain for hours without apparent injury in a temperature of about −216° C (216 degrees below the freezing temperature of water). The higher animals and plants have a much narrower range of temperature in which they are able to survive than some of the lower forms of life. Man, however, by applying science is able to endure the low winter temperatures of the polar regions and of the atmosphere several miles above the earth.

Oxygen. Oxygen composes about 21 per cent of the volume of the air. A knowledge of its properties is of value in the study of biology.

Experiment 2. What are some of the characteristics of oxygen? Mix thoroughly three parts of potassium chlorate and one part of manganese dioxide which is thoroughly dry. [**Caution.** *Do not grind, because of the danger of causing an explosion.*] Arrange the apparatus as in the figure. Heat the mixture in a test tube by gently passing the flame back and forth over the test tube. After the gas has escaped from the tube for a few seconds, collect two or three bottles of it. Thrust a glowing wooden splint into one bottle of oxygen. Does the splint flame up, or is the glowing coal extinguished? The true color and odor of oxygen cannot be noted immediately after it has been collected in this way. Summarize in a statement all the facts which you have learned about oxygen in this experiment.

*Oxygen is used in the life processes of all living things. There are many animals and plants which cannot take their oxygen directly from the air, as men and other higher animals do. For example, fish "drown" if they are

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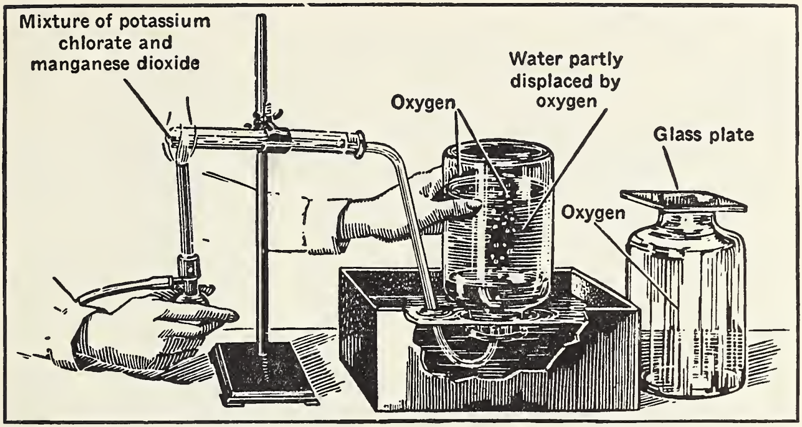
[1] To the Teacher. See the *Teachers' Manual* for suggestions relating to experiments, projects, and the like.

[2] *Germination* (jûr mĭ nā'shŭn): the process of starting growth, as of a young plant from a seed.

[3] **See "Elements of Scientific Method," p. 625.**


Mixture of potassium chlorate and manganese dioxide
Oxygen
Water partly displaced by oxygen
Glass plate
Oxygen

Making oxygen. Why is it better to collect oxygen over water, as is being done here, than in air-filled bottles?

exposed to air for more than a short time. Oxygen is around them in abundance, but they are unable to use it unless it is dissolved in water. Some bacteria (anaerobic)[1] cannot use oxygen either in the form of a gas or when it is dissolved in water. They can use it only when it is combined with certain other substances.

Water. *Water is given off as a waste product by every living thing. Therefore every organism must constantly secure a fresh supply of water. Most plants and animals must secure water at relatively short intervals. Some of the lower plants and animals, however, are able to exist for long periods without renewing the water in their bodies. For example, certain Australian frogs can live buried in the dry earth for as long as two years, and certain bacteria can live for months away from water.

Rainfall operates powerfully in controlling life. The plants and animals which live in desert regions are usually very unlike those which live in regions where there is abundant water. They must be different in structure and in habits[2] in order to survive. For example, if a cactus and a horned toad from the desert in the southwestern United States were to exchange habitats with a water lily and a frog, neither pair would be able to live long in the habitat of the other.

When for any reason the supply of water becomes too scanty for the needs of living things in any region, the plants and animals must (1) some-

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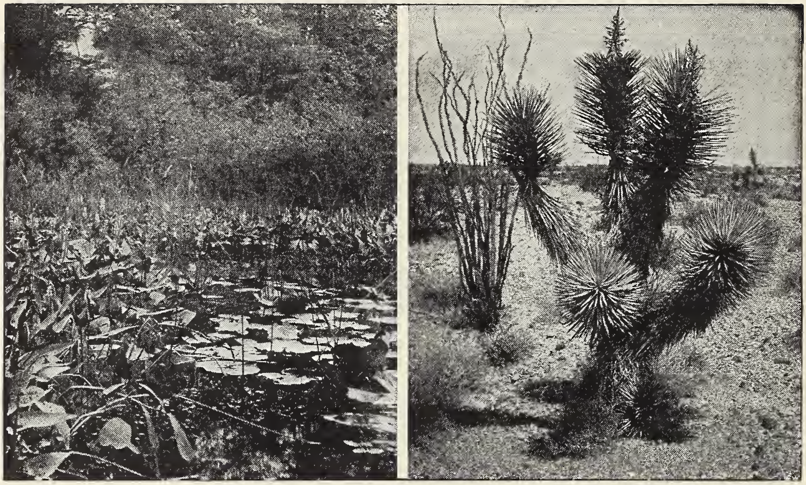
[1] Terms in parentheses in the text and labels in parentheses in the illustrations are not intended as essential vocabulary (see the Preface, p. v).

[2] See the Glossary.



Water plants in a pool and desert plants of the Southwest. **Self-test on Biological Principles:** How do these pictures illustrate this principle: "Water affects the abundance of life"?

how adapt, that is, adjust, themselves to living for longer intervals without water, or (2) increase their water supply artificially, or (3) migrate to a more favorable habitat, or (4) die.

Only man and a few of the other higher animals, such as the beaver, can increase their water supply artificially by storing it or by bringing it from lakes or rivers.

The animals and plants of a region are sometimes able to adjust themselves to a changing water supply over a long period of years, provided the change occurs very slowly. In such cases the plant or the animal itself becomes changed to a greater or a lesser extent. Thus desert plants and animals have become adapted to a habitat in which months or even years may elapse between rains. Such living things have become able (1) to store water in their bodies, (2) to get along with an exceedingly small amount of it, and (3) to eliminate it very slowly.

Every habitat limits the numbers and kinds of animals. Water as a habitat is an important factor in thus limiting life. The extent to which it limits life depends on (1) whether the habitat is entirely water or is dry land; (2) whether it is shallow water or deep water; (3) whether it is fresh water or ocean water. We are all familiar with the fact that animals and plants which live entirely in the water are very different from those which live

Fish that live in the deepest parts of the ocean. These fish live four or five miles below the ocean surface, where there is enormous pressure and no light except that which they themselves produce. Explain why there is relatively little life in the ocean depths

entirely upon the land. Fish and water plants soon die if removed from water, while land animals and plants suffer the same fate if they are kept under water. Moreover, the animals and plants which inhabit the shallow water of fresh ponds and the margin of the ocean are very different from those which live in the deep waters of the Great Lakes and the ocean.

Some animals and plants—for example, the salmon and certain of the bacteria—can live both in fresh water and in ocean water. Others, such as goldfish and pond plants, cannot live if they are taken from fresh water into the ocean. Still others die if they are taken from the ocean into fresh water. An example of this latter type of animal is the barnacle. This animal lives fastened to rocks or to floating objects, such as the bottoms of ships. If, however, the ship enters a fresh-water harbor, the barnacles all die and drop off or are easily removed. Another example is furnished by sponges. These animals sometimes fasten themselves upon the shells of oysters in such numbers as to starve the oysters by robbing them of their food supply. In order to prevent this, "oyster farmers" sometimes grow their oysters upon frames. When it rains, they raise these frames above the salt water. The rain soon kills the sponges. But the oysters, protected by their shells, are unhurt by it.

Instructions for Taking the Tests. At the end of each section you will find tests which will enable you to determine whether or not you know and can apply the important facts in the section. If you are not able to answer all these test items correctly, review the section. (*Do not write in the book.*) These tests will be of several types, but chiefly of the following three types:

The Modified True-False Type. In each of the items of this type one or more words are italicized. If the statement as given is not correct, make it correct by changing one or more of the italicized words, thus:

1. Biology is the study of *all living* things. [This statement is correct as given and needs no changes.]
2. Biology is the *science* which deals with the study of *rocks.* [This statement is not correct as given, but can be made so by changing *rocks* to *living things.*]

The Completion Type. Make each of the items of this type a complete and correct statement by supplying a word or phrase in the blank indicated by --?--, thus:

The science which has to do with the study of all living things is --?--. [You would make this statement correct by adding the word *biology* in the blank.]

The Modified Multiple-Response Type. Each item of this type has five or more endings. In some items the correct endings are among those given. In others they are not. You are to decide in each case whether the correct ending is present. If it is, indicate it. If it is not, supply the correct ending to make the statement true.

An example of the type in which the correct ending is given is this:

The science which has to do with all life is (1) chemistry; (2) physics; (3) biology; (4) geology; (5) paleontology; (6) botany; (7) astronomy. [The only one of the seven endings given here which is correct is (3) biology.]

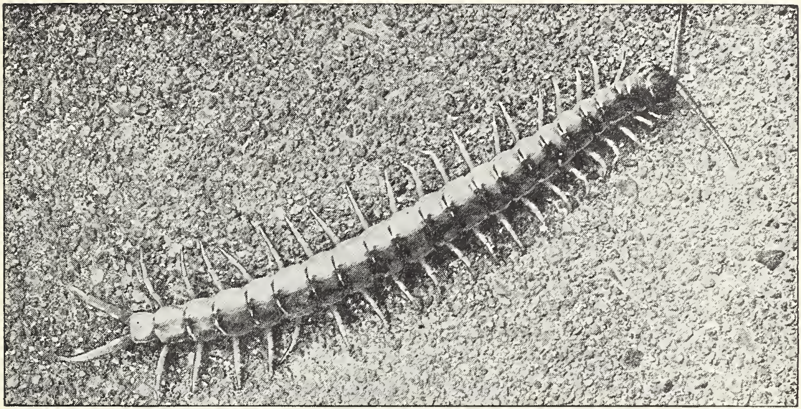
Sometimes in this type of item there will be several endings each of which is more or less correct. In such a case you are expected to select the best ending.

An example of the type in which the correct ending is not given is this:

The science which has to do with all life is (1) chemistry; (2) physics; (3) horticulture; (4) geology; (5) paleontology; (6) botany; (7) astronomy. [None of the seven endings makes the statement correct; hence you would supply the correct ending, *biology.*]

The explanations of how to answer other types of self-test items will be given with each type as it appears.

Self-test. 1. A cow or a horse could not live at the north pole or the south pole, because (1) there is no sunshine at the poles; (2) nothing can live at the poles; (3) such an animal cannot live without man's protection; (4) there are no green plants at the poles; (5) such an animal would find no food at the poles; (6) there is no water at the poles.



Cornelia Clarke

A centipede. In what sort of environment should you expect to find the centipede?

2. *Few* plants and *no* animals can exist without securing food.

3. A rapid increase in the number of animals or plants in a desert may be due to a sudden *decrease* in the amount of rainfall.

4. Oxygen is necessary to *most* plants and to *some* animals.

5. If the earth should ever be without heat, *most* life would cease.

6. Suppose some wild animal, such as a deer or a bear, should be living in a locality in which no rain fell for several years. What would the animal need to do in order to survive?

WHAT OTHER FACTORS OF THE ENVIRONMENT ARE IMPORTANT TO LIVING THINGS?

Light. Light is essential to green plants in their manufacture of food. Hence it is necessary, directly or indirectly, to all organisms. Some animals and plants, however, can live in the dark. Fish with undeveloped eyes, but otherwise similar to the same kinds of fish found elsewhere in rivers and lakes, have been found in the river flowing through the Mammoth Cave of Kentucky. Some of the animals in the depths of the ocean live without any sunlight whatever. So also do parasites[1] which live entirely within the bodies of their victims, or hosts. Many animals—for example, the centipede and the sow bug—avoid light. Such animals are harmed if compelled to remain long in intense light. Some of the bacteria cannot exist except in complete darkness. All bacteria are killed by long exposure to direct sunlight.

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[1] *Parasite* (păr'*ȧ* sīt): any living thing that lives inside or upon, but always at the expense of, some other living thing. *Parasitic* (păr *ȧ* sĭt'ĭk): having the nature or habits of a parasite.

The amount of sunlight during the year in various parts of the earth determines to a large extent the numbers and kinds of plants and animals.

Carbon dioxide. About one three-hundredth of the air is carbon dioxide. This gas is necessary to all green plants in their work of food-making. It is therefore necessary, directly or indirectly, to all living things. Some of the characteristics of carbon dioxide can be learned from an experiment.

Experiment 3. What are some of the characteristics of carbon dioxide? Place about a tablespoonful of soda in a tumbler. Add enough vinegar, lemon juice, or other acid to cause violent effervescence, or bubbling. The gas formed is carbon dioxide. After a few seconds note the color of the carbon dioxide in the top of the tumbler. When the effervescence stops, dip a glass rod into limewater. Then immediately thrust the wet end of the rod into the carbon dioxide in the tumbler. What color does the limewater on the rod become? Thrust a glowing splint into the carbon dioxide. Does the splint light? What happens? Thrust a lighted splint into the carbon dioxide. What happens? Summarize in a statement all the facts you have learned about carbon dioxide from this experiment.

Shelter. Shelter is essential to some living things during part of their lives and to others during all their lives. Many plants can live only provided they happen to grow where they are sheltered from intense sunlight, strong winds, or other extreme conditions. Some animals can find such shelter as they need, but others must make their own. Bears and many other animals spend the winters in underground caves or in hollow stumps. Insects and snakes seek holes in the ground or cracks in deep rock. Many plants and animals are sheltered by the snows against the winter cold.

All parasites which live inside the bodies of other organisms must have the shelter of the bodies of their hosts in order to survive. The fur or feathers of some animals furnish shelter to such parasites as fleas and lice.

Many living things make shelters. Insect larvae[1] of many kinds make cases (cocoons), in which they live safely while developing into the adult, or full-grown, state. Some insects bore holes in trees or dig holes in the ground which serve as shelters for their eggs and larvae. Birds and some kinds of fish build nests in which to shelter their young. The young of all the higher animals are sheltered before birth in the bodies of their mothers. Many animals, such as beavers, squirrels, and mice, build shelters in which to spend the winters.

Land formations and bodies of water (physiographic features). Mountain ranges, deserts, rivers, plains, forests, and oceans sometimes serve as barriers which hold certain kinds of animals and plants more or less within certain boundaries. Thus Australia has a number of animals, such as the kangaroo

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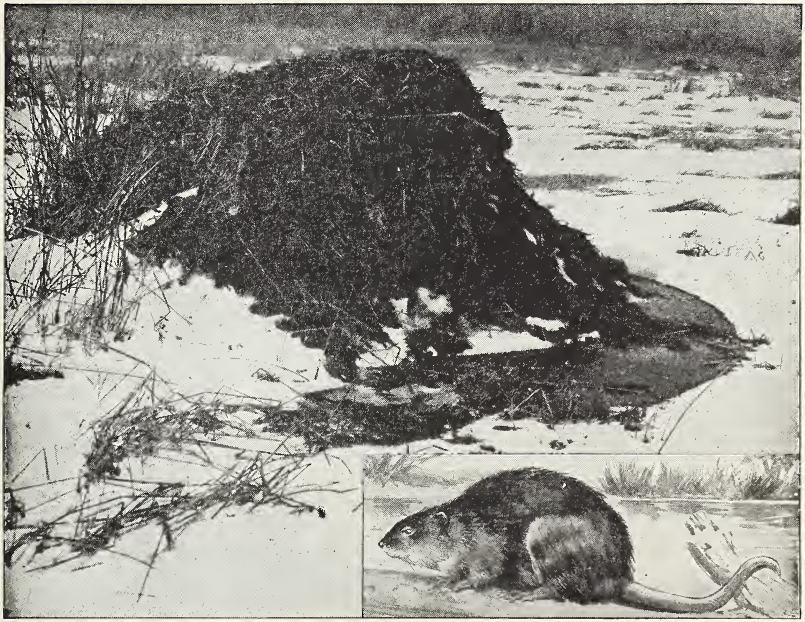
[1] See the Glossary.



Lynwood M. Chace

Muskrat house and muskrat. The muskrat enters his house through a tunnel, the outside opening of which is under water. What advantages are there in this type of shelter?

and the platypus (see pages 575 and 233), which, because of the oceans surrounding Australia, have not spread to other lands.

Weather and climate. Weather conditions are responsible for temporary changes in the animal and plant population. If the winter is unusually cold, the insect population is likely to be less during the following summer than if the winter is mild. Sometimes fruit trees and nut trees have almost all been killed in certain sections as the result of a winter of severe and long-continued cold. Similarly, unusual periods of drought or of wet weather affect greatly the number of plants and animals. Such conditions not only reduce or increase the food supply but also may produce conditions that make difficult or impossible the existence of various kinds of animals and plants.

Contrary to the belief of many people, climates do not change except over long periods of hundreds or thousands of years. Nevertheless they do gradually change. As climates change, the plants and animals which can live in them must likewise change, or they must migrate. Fossils[1] of animals closely

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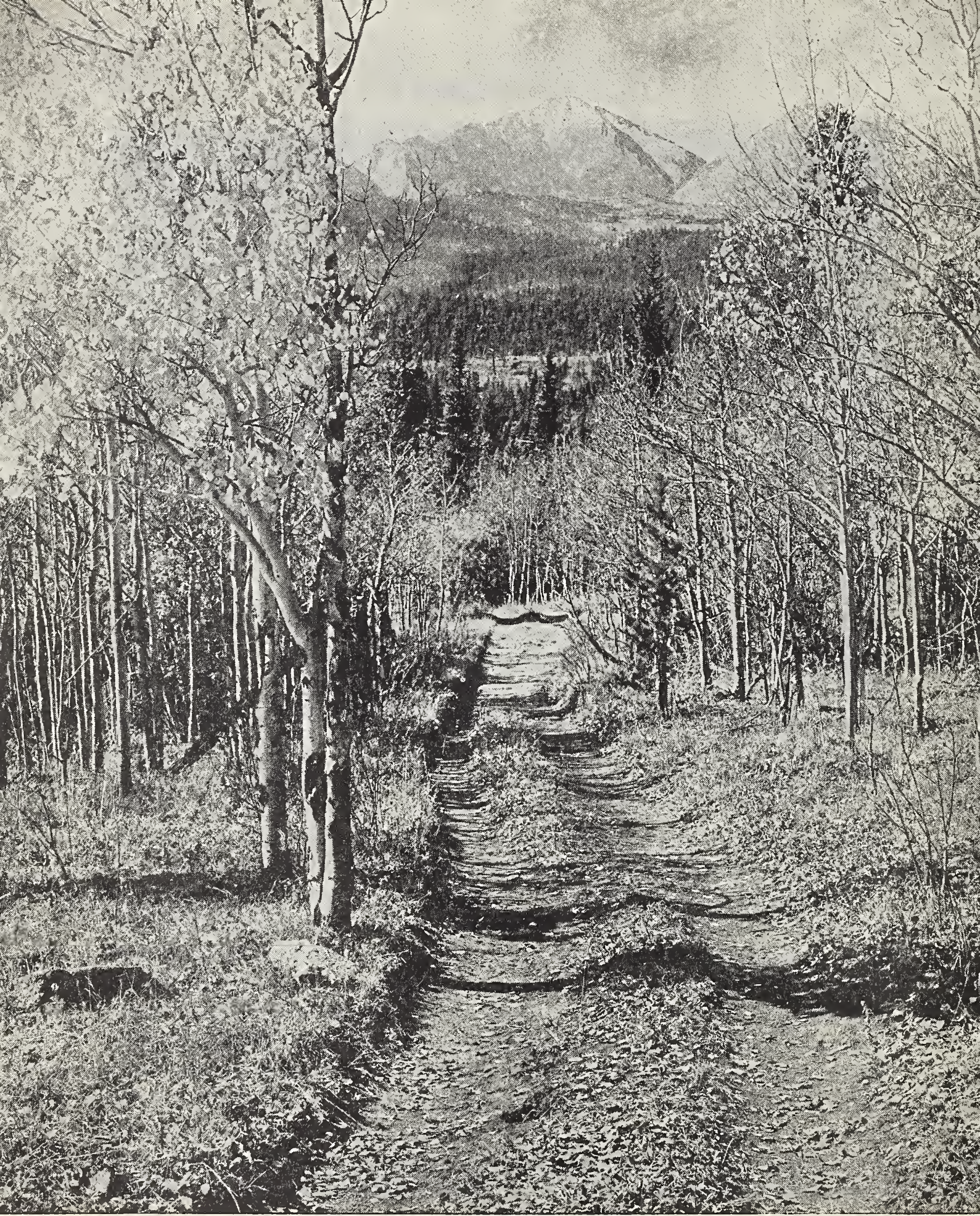
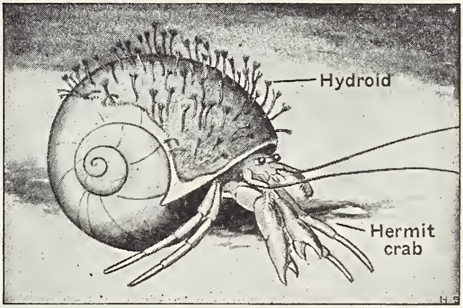
[1] *Fossils* (fŏs′ĭlz): the forms or remains of ancient plants or animals preserved in earth or rock.



Colorado Association

Biological succession, Rocky Mountain National Park. Gradually the evergreens will take the places of the deciduous trees (aspens). Can you suggest reasons to account for this statement?

related to elephants have been found in various parts of this country. Even the arctic regions have revealed fossils of animals that could have lived only in climates very different from the arctic climate of today.



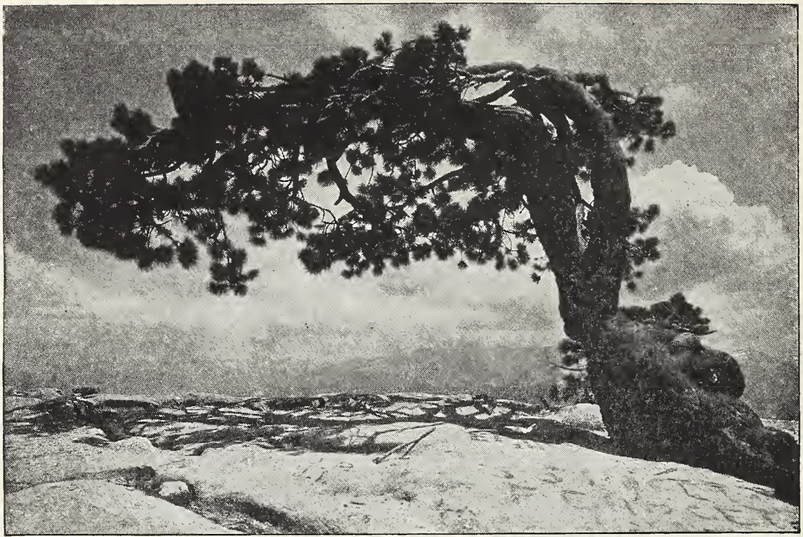
A hermit crab in a seashell. Hydroids are growing on the shell. The hermit crab can survive only by finding an empty shell into which to thrust its tender body for protection. **Special Report: The** hermit crab

Thousands of years ago (during the glacial age) vast sheets of ice covered much of the Northern Hemisphere. For many centuries Alaska, Canada, and the northern part of the United States lay under the ice. No life was then possible in these regions. At other times much of the central United States was covered by dense tropical forests. Whether the climate is tropical, temperate, or arctic determines largely the nature and abundance of life. Thus certain trees and other plants and animals are found only in certain regions because of the climate in these regions.

Soil. The nature of the soil and its depth determine to a great extent the numbers and kinds of animals and plants which can inhabit a given region. The higher forms of plant life, such as trees, do not thrive where the soil is shallow or scanty. Any boy who has hunted for earthworms knows that he is not likely to find them in heavy clay or in sand, but that they are likely to be abundant in soil that is rich in decaying animal and vegetable matter. Other soil conditions which limit plant and animal life will be discussed in later chapters.

Relations among living things. Plants and animals, especially man, are themselves limiting factors of life. Plants struggle with one another for the possession of space and sunshine. Animals and some plants feed upon other animals and plants. Most diseases of animals and plants are caused by parasites of one sort or another.

Here and there in nature are found certain curious associations of two different kinds of living things. Life in the environment in which they live would be difficult or impossible for either alone. Together they survive because each contributes something necessary to the other's welfare. Thus in the shallow water on the ocean beach one often finds a little hermit crab. Sometimes one finds several small plantlike animals (hydroids) growing on



A. M. N. H.

Pine tree at timber line, Yosemite valley, California. **Exercise on Scientific Method (Making Inferences):** How do you explain the unusual form of this tree?

the same shell that the crab occupies. These animals benefit the crab as well as themselves because with their stinging organs they keep enemies away from the shell. They benefit from their association with the crab, since, by being carried about as the crab drags the shell along, they secure more plentiful and varied food than they would if anchored to a rock. Such a helpful association is an example of symbiosis.[1]

Another example of symbiosis is supplied by the rhinoceros and a certain species of bird. The bird profits from the association by eating insect parasites from the rhinoceros's back. The rhinoceros profits by getting rid of its parasites and also by being warned by the behavior of the bird when danger approaches.

Changes in the environment. Many changes due to natural causes often prove limiting factors of life. A forest fire renders the burned section unfit for many kinds of plant and animal life for many years. Sands shifting slowly but steadily year by year may not only kill vegetation in their path but render the region unfit for new vegetation. Ashes and fumes from an active volcano may so cover the surrounding country as to make life of any sort impossible.

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[1] *Symbiosis* (sĭm bĭ ō'sĭs): such an association of two totally different living things as results in benefit to each.

***Summary.** The preceding discussion has shown that certain factors of the environment are directly necessary to all life. These are food, heat, oxygen, and water. Other factors which are necessary, directly or indirectly, are light, carbon dioxide, and shelter. The numbers and kinds of animals and plants depend on the abundance of these factors. Other factors which affect the numbers and kinds of organisms in a region are the land formations and the bodies of water of the region, weather and climate, the depth and the character of the soil, other animals and plants living in the region, and changes in the environment due to natural causes. When any animal or plant finds conditions unfavorable to its existence, it must (1) migrate, (2) adapt itself to the changing conditions, or (3) be exterminated.[1]

Self-test. **1.** Select from the following list of factors those which are directly necessary to all life: (1) light; (2) other living things; (3) water; (4) favorable weather; (5) soil; (6) extermination of some other plant or animal; (7) food; (8) shelter; (9) heat; (10) slow changes in the environment; (11) oxygen; (12) migration to other regions; (13) oceans; (14) plains, rivers, and mountains; (15) man; (16) rainfall; (17) carbon dioxide.

2. Is there any factor which no living thing would ever need?

3. A wood-tick that buries its head in the body of a dog and lives on the dog's blood is an example of *symbiosis.*

Self-test on Important Biological Terms. Explain in your own words each of the terms in this list and, if you can, illustrate each with an example of your own. Consult the Glossary freely.

energy
fossil
germination
habitat
parasite
symbiosis

Self-test on Biological Principles. What evidence can you cite from this chapter to illustrate this biological principle: "The environment acts on living things, and living things act on their environment"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. **1.** Why were the polar explorers unable to use the abundant energy of the sun in the polar regions?

2. What observations have you made which indicate other ways than those given in this chapter in which living things are affected by light?

3. Below the falls of the Zambezi River, in Africa, is a small island upon which the mist from the falls descends like rain without ceasing. Can you name animals and plants which you feel certain could not survive in such a habitat? What should you expect would be some of the characteristics of the plants which do live there?

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[1] *Exterminate* (ĕx tĕr′mĭ nāt): to kill all living things of a certain kind. *Extermination* (ĕx-tĕr mĭ nā′shŭn): act of exterminating.

4. What examples of artificial shelter other than those mentioned in the text can you name? Can you name any animals or plants which can live their entire lives without shelter of any sort?

5. Can you name other examples than those discussed in this chapter of plants and animals which can exist only under certain soil conditions?

6. How does man's progress toward making homes and cities more sanitary serve as a factor limiting certain kinds of life? Can you name other activities or achievements of man which serve as factors limiting life?

7. Can you name other examples of changing environment, similar to those mentioned, which might limit life?

8. What animals and plants can you name that have become extinct in your locality during the last century or so? Can you name any animals or plants which have entirely disappeared from the world during the past few hundred years? Can you learn the causes of their disappearance?

9. How does the habit of symbiosis aid certain plants and animals to survive?

Special Reports. 1. During the Second World War, battles between squadrons of airplanes were commonly fought miles above the earth's surface. The air at such altitudes is so thin that it does not contain oxygen enough to support life. Furthermore, the temperatures at those heights are so low as to present a constant danger to aviators. How are aviators provided with sufficient oxygen and how are they protected against the extreme cold?

2. During the Second World War, in the jungles and other places where pure water was not available, each soldier carried his own water-purifying kit. How is this purifier constructed and how does it operate? Against what enemies did these water purifiers protect the men?

3. In Chapter II you have been introduced to *parasitism*, which is a sort of partnership in which one plant or animal lives at the expense of another. You have also learned something about *symbiosis*, in which two living things—for example, two plants, two animals, or a plant and an animal—live together in another sort of partnership, in which each profits from the life activities of the other. There are many variations between true parasitism and true symbiosis. In some cases a plant or an animal will live inside, upon, or with another, and will neither harm nor benefit its host, but will nevertheless gain some benefit to itself. Such a relationship is known as *commensalism*, and the partners are called *commensals*. In "big" dictionaries, and in encyclopedias, in textbooks of college zoology and botany, and in such books as Wells, Huxley, and Wells's *The Science of Life* you will find many examples of commensalism. List them, and in each case try to decide what benefit one partner derives from its association with the other. Decide, also, to which of the biological principles on pages 626 and 627 these examples apply.

CHAPTER III

Living and Nonliving Things

Questions This Chapter Answers. 1. What is protoplasm, and what are its characteristics? · 2. What are the functions of protoplasm? · 3. What is the cell theory? · 4. What are the characteristics of a cell? · 5. What are tissues and organs? · 6. How are living things like and how are they unlike nonliving things? · 7. What are some of the characteristics of elements, compounds, and mixtures? · 8. What are the characteristics of organic and inorganic matter? · 9. What is the relation of oxidation to energy? · 10. What are physical and chemical changes? · 11. What is osmosis?

WHAT ARE THE CHIEF CHARACTERISTICS OF LIVING MATTER?

The nature of protoplasm. An elephant does not apparently resemble an oak tree, nor does a cat seem much like a cabbage. Yet these plants and animals are much more alike than they appear because the living parts of all plants and animals are composed of the material called protoplasm.[1]

*Protoplasm is neither solid nor liquid. It is somewhat like raw white of egg and somewhat like jelly. It is also to a slight extent elastic. Most protoplasm is almost colorless, slightly yellow or gray, and is usually transparent. Some protoplasm appears to be full of bubbles. Other protoplasm looks as if it were made up of little grains.

Protoplasm is never exactly the same in two different kinds of plants and animals. Moreover, it differs somewhat in different parts of the same living thing. Also, it is constantly changing, wherever it is.

Only the living parts of animals and plants are protoplasm. Heart-wood of trees, fingernails, and the bony parts of teeth are not protoplasm, though all these are produced by protoplasm.

The functions of protoplasm. *All protoplasm, wherever it exists, carries on certain functions, such as nutrition, respiration, growth and reproduction, irritability, and excretion. These terms are introduced and briefly explained here. They will be discussed in more detail later.

(1) Nutrition is the process of utilization of food by living organisms. (2) Respiration includes breathing and several related processes within the protoplasm which accompany the use of oxygen. (3) Growth is the process by which organisms increase in size. (4) Reproduction is the process by which new individuals are produced. Both growth and reproduction result in the production of new protoplasm and hence are closely related to each other. (5) Irritability is the ability to respond to influences, such as heat, chemicals, jarring, light, sights, odors, and sounds. (6) Excretion is the process of getting rid of waste products.

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[1] Consult the Glossary for the pronunciation of scientific terms.

Armstrong Roberts

How does this picture illustrate irritability?

Since all the living parts of every animal or plant are composed of protoplasm, every organism passes through certain stages of development. It starts life as an individual, it grows to maturity, it becomes old, and finally it dies. Moreover, since the living parts of every animal and plant are protoplasm, it follows that every living thing must carry on the functions of protoplasm which have been mentioned.

The cell. A study of protoplasm properly starts with a study of cells. Experiment 4 will acquaint you with the chief structures of cells.

Experiment 4. What are some of the characteristics of a living cell? With a knife remove some of the thin skin from one of the layers of an onion. Mount a single thickness of this on a microscope slide. Put a drop of water on the specimen and place a cover glass over it. Adjust the slide under the low-power objective of a compound microscope. What do you see? You are now observing living cells. Add to the material on the slide a drop of weak tincture of iodine or of a solution made by dissolving iodine crystals in water. Do you now observe any structures in addition to those which you saw before you stained the slide? Make a careful study of the materials under the high-power objective. Make sketches and record your observations so that you will have a complete report of your study of onion cells.

With a knife blade or a toothpick scrape some of the material from the inside of your cheek. Transfer a little of this material to a microscope slide. Study the epithelial[1] cells in it in the same manner in which you studied the cells in the onion skin. Study also the cells of *Pleurococcus*, of the young leaves of *Elodea*, or of the hairs on the young stems of a squash, a geranium, or a spider lily (*Tradescantia*). Do you find any structures in any of these cells which were not present in the onion?

From your observations of these various kinds of living cells, what have you learned concerning the characteristics and structure of the cell?

Evaluate these procedures[2] by answering the following question:

Why was it desirable to examine a number of different kinds of cells?

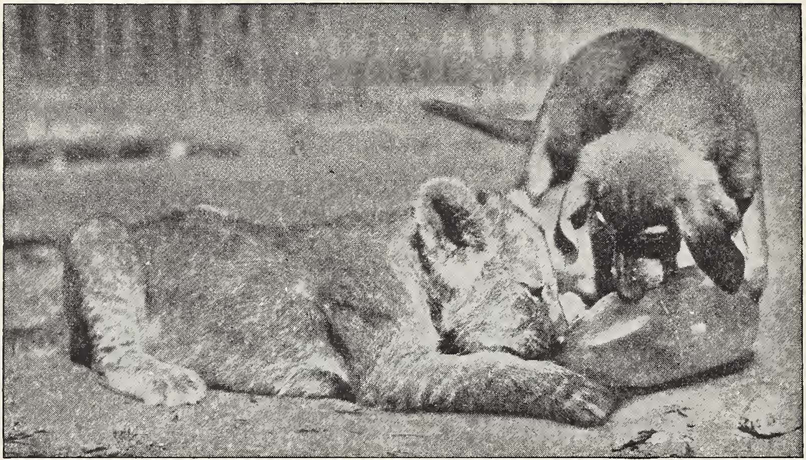
The earliest knowledge of cells was obtained from a study of plant structures. In 1665 Robert Hooke, while studying a section of cork under a lens, saw that the cork had a regular arrangement of little spaces. These he called cells because they reminded him of the cells, or rooms, occupied by monks in a monastery. Since cork is dead material, he saw only the cell walls. Protoplasm was not discovered until more than a hundred years later. Thus for a long time the cell walls were considered the most important part of the cell.

*In 1838 Schleiden, from a study of plant structures, first announced the

---

[1] *Epithelial* (ĕp ĭ thē′lĭ ăl): having to do with the epithelium, or the layers of cells covering the surfaces of the body and of such organs as the mouth and nose.

[2] See "Elements of Scientific Method," p. 625.



Newton H. Hartman

Lion cub and pup, each three months old, Philadelphia zoo. What functions of protoplasm are illustrated here?

theory that all plants are made up of cells. Schwann, working with animal structures, had formed a similar theory with respect to animals. Schwann combined Schleiden's theory with his own and as a result, in 1839, announced the principle that is now known as the *cell theory*. This principle states that the cell is the unit of all life and that all plants and animals are made up of cells.

Some of the work of Schleiden and Schwann was inaccurate. Therefore some of their conclusions from their observations are now known to be false. Nevertheless the modern cell theory, which has been built on the work and publications of these two men, is regarded as one of the "foundation stones of biology."

The nature of the cell. Each of the simplest plants and animals consists of only one cell. All others consist of more than one cell, and some are made up of billions of cells. Most animal cells are small, usually about three times as long, wide, and thick as this page is thick. There are some single-celled organisms so small that they cannot be seen even through the strongest microscope. In contrast with these, certain one-celled animals are nearly an inch long by an eighth of an inch broad and thick. Certain nerve cells are several feet long. These, however, are thread-like and are not more than one thousandth of an inch thick. Plant cells are in general larger than animal cells.

Robert Hooke at his microscope. With his microscope he studied an endless number of objects, among them fish scales, flies' feet, and nettle stings. Which of the scientific attitudes (p. 624) does his work represent?

The size of a plant or an animal depends not on the size of its cells, but on the number of cells which compose its body. The larger the animal or plant, the more cells it contains. The gray matter in the human brain is estimated to contain nearly ten billion cells.

*Every living cell is composed of protoplasm. This protoplasm consists of two parts, the cytoplasm and the nucleus. The cytoplasm, which is thin and watery, occupies almost the entire cell. If you were observing closely in Experiment 4, you may have seen the cytoplasm moving within the cells of *Elodea*, geranium hairs, or squash hairs. The nucleus is a round body somewhat more dense than the cytoplasm, and is partly or wholly surrounded by cytoplasm. A few cells have been observed which have no definite nucleus, but these have materials such as compose a nucleus scattered about in the cytoplasm. The cytoplasm and the nucleus, therefore, are essential parts of every living cell.

Various kinds of cells may contain special structures. Some animal cells, for example, contain drops of fat. Plant cells often contain vacuoles. These are regions filled with air or sap. Each cell has around it a thin layer of denser cytoplasm (called the cell membrane) which holds the cell together and prevents the escape of the rest of the protoplasm. Some cells have in addition a harder covering, or cell wall. In most plant cells this wall is composed of a firm material called cellulose. No animal cells have cellulose walls. Therefore, in general, animal cells can be more easily changed in form by pressure than plant cells.

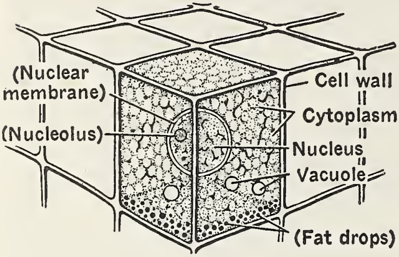


Diagram of a cell.[1] The cell is the unit of matter. Explain

The cells in an animal or plant are not entirely separate units. During their active period, adjoining cells are connected through their walls with minute threads of cytoplasm. Other structures of the cell and the functions of the various cell structures will be discussed later.

Tissues. *In Experiment 4 an examination of the onion skin and of material from the inside of the cheek showed many similar cells in each specimen. Cells are much alike in any one kind of material, but very unlike in different kinds of material. A group of similar plant or animal cells which exist together and are adapted for a similar purpose is called a *tissue.* Thus in the human body there are epithelial tissue, muscle tissue, nerve tissue, and many other kinds of tissue. The tissues that are found in one kind of animal or plant are never exactly like any tissues found in any other kind of animal or plant.

Organs. *Groups of tissues together form *organs.* The simplest organs may be made up of only one kind of tissue. Usually, however, an organ is composed of several kinds of tissues, each performing certain functions. Thus in such an organ as a plant leaf, the outer tissue protects the tender inner parts and performs other useful functions. Tissues inside the leaf are concerned with the manufacture of food. Veins of tissue running through the leaf give support and shape to the leaf. In an organ like the human hand there are muscle tissue, nerve tissue, bone tissue, and several other kinds of tissue.

Self-test. 1. Which of the following words or phrases describe protoplasm: (1) solid; (2) somewhat like jelly; (3) reddish brown; (4) slightly yellow or without color; (5) sometimes appears to be made of grains; (6) usually permits objects to be clearly seen through it; (7) always living; (8) every bit like every other bit?

2. Name other qualities of protoplasm which are not listed in 1.

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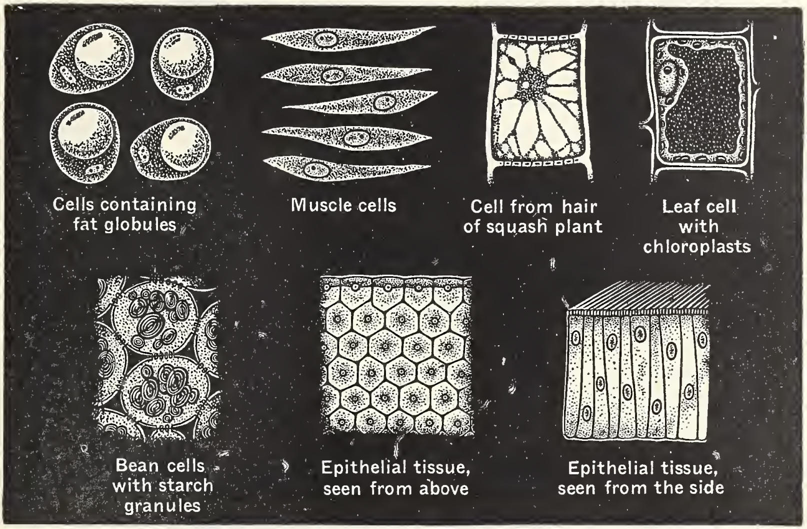
[1] Terms in parentheses in the text and labels in parentheses in the illustrations are not intended as essential vocabulary (see the Preface, p. v).


Cells containing fat globules
Muscle cells
Cell from hair of squash plant
Leaf cell with chloroplasts
Bean cells with starch granules
Epithelial tissue, seen from above
Epithelial tissue, seen from the side

Compare these plant and animal cells. (See "How to Study," p. x.) How many reasons can you give why different kinds of tissues are not alike?

3. One, but not more than one, item in *A* describes or illustrates each of the items in *B*. Match each item under *B* with one under *A*. The items under *A* may be used more than once in matching different items under *B*.

A

a. Nutrition
b. Young pig
c. Excretion
d. Unit of living structure
e. Respiration
f. Irritability
g. Toenail
h. Reproduction
i. Organ
j. Tissue
k. Oxygen

B

1. Answering when somebody speaks to you
2. A mother cat and her kittens
3. The ear
4. Eating an apple
5. Taking a deep breath
6. Getting rid of excess salt along with perspiration

4. *Most* living cells can be seen with the eye.

5. A *tissue* is composed of many similar cells.

6. All living things are composed of *organs.*

7. The eye is an example of *a tissue.*

HOW DOES LIVING MATTER DIFFER FROM NONLIVING MATTER?

Comparison of living and nonliving[1] things. Living things are composed of protoplasm; nonliving things are not. This fact constitutes only one important difference between living and nonliving things. It is, however, probably related closely to all the other differences. These differences relate to form, size, structure, growth, reproduction, and movement.

1. *Form.* We are able to recognize dogs of any size as dogs, or trees of any size as trees, because they have the same general form. It is only because animals and plants look considerably like other animals and plants of the same kinds that we can tell the different kinds apart. Nonliving bodies cannot in most cases be distinguished by their forms, or shapes. Thus metals and most rock can be of any shape. Also, a liquid or a confined gas always takes whatever shape the vessel that contains it has.

2. *Size.* There is an enormous difference in size between the microscopic[2] living things and the greatest trees or the great animals, such as the whale and the elephant. Yet the size of any living thing is limited. Moreover, living things of the same kind seldom differ very greatly in size. These statements are not true of nonliving things. Thus a rock may be an invisible grain of dust or a mountain. Water may be an invisible particle of vapor in the air, or it may be an ocean. In contrast, full-grown men vary in size from slightly less than four feet to somewhat more than nine; but the tiny men and the giants of fairy tales are creatures of the imagination only.

The struggle for life is such that no animal or plant can continue to live if it varies greatly from the size which is most favorable to the continued existence, or survival, of that particular kind of organism.

3. *Structure.* If we were to study bits of metal, rock, or any other nonliving things as we studied the living tissues in Experiment 4, we should find no cells. Nonliving things have no unit of structure which is similar to the cell or which could even be compared with it.

4. *Growth.* Organisms do not become larger simply by an increase in the size of the cells, because each kind of cell has a limited size beyond which it cannot grow. Growth in living things results from an increase in the number of cells as the cells produce new ones. In this way new material is added to every living part of a plant or animal. In contrast, non-living objects can increase in size only by having more material added to them on the outside. Thus they do not really grow in the sense that plants and animals do.

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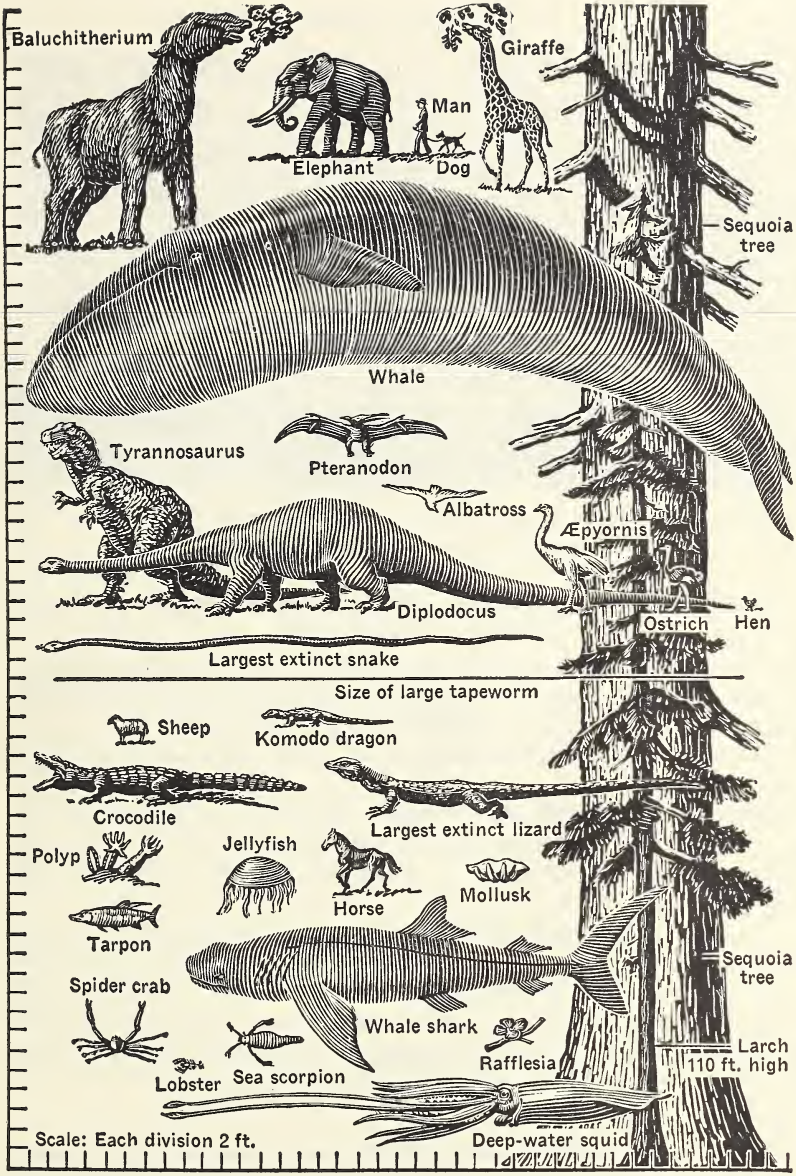
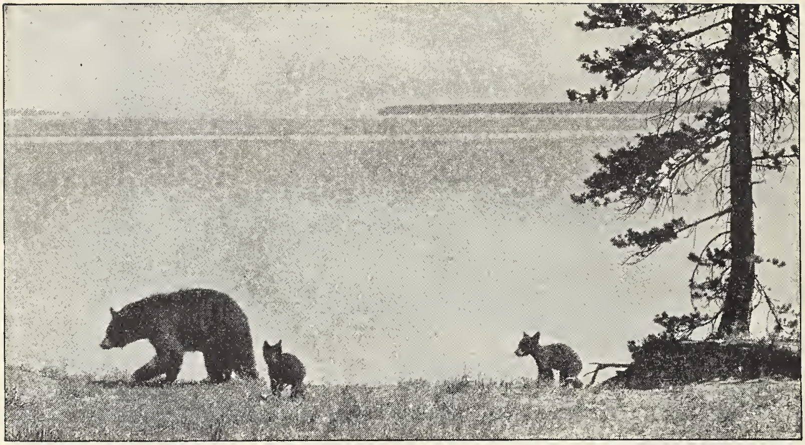
[1] In the following discussion *nonliving* things are things like rocks and water, which are not alive and never have been alive. *Nonliving* does not here refer to dead plants and animals.

[2] *Microscopic* (mī krō skŏp'ĭk): too small to be seen except through a microscope.



These are the largest animals and plants of their kinds that ever lived on the earth. Are they ancient or present-day specimens?[1] The man, the dog, and the hen are added to give a basis for comparison of size

[1] After a drawing by L. R. Brightwell from Wells, Huxley, and Wells's *Science of Life.*



United States Bureau of Biological Survey

Mother bear and cubs, Yellowstone Lake, Wyoming. What differences between living and nonliving matter are illustrated here?

5. *Reproduction.* Living things produce young, which grow to resemble their parents. Nonliving things do not reproduce.

6. *Movement.* Some living things are able to move about from place to place at will. Even those that remain anchored in one spot have movements of various kinds. Nonliving things have no such movements.

There are other differences between living and nonliving things which will be discussed later.

Elements, compounds, and mixtures.[1] *Some facts about matter in general will help you to understand the nature and activities of protoplasm. There are three classes of substances: elements, compounds, and mixtures.

An element is a simple substance which cannot be broken up into any simpler substances. Thus the element iron is always iron and can never be anything else. There are ninety-two elements. These by themselves or in various combinations with one another make up every substance that exists. The characteristics of common elements, such as oxygen, carbon, nitrogen, and hydrogen, are especially important in the life processes of every living thing.

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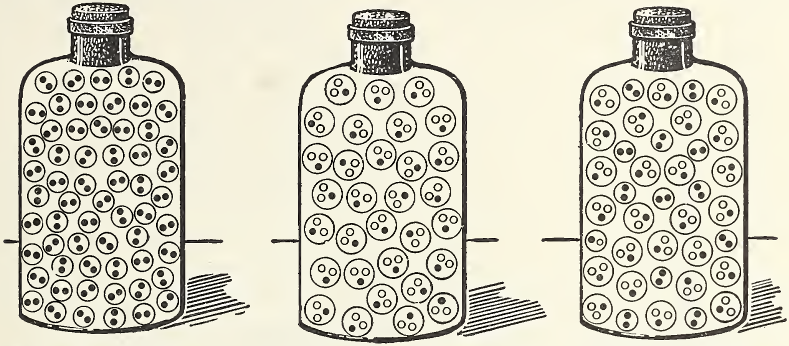
[1] To the Teacher. Much of the material included in the remaining pages of this chapter is discussed in all courses and textbooks of general science. It is included here to provide a desirable review for the pupils who have studied it earlier and also to provide a necessary background for those who have not.

Elements are composed of exceedingly small particles called atoms.[1] One or more atoms make up a molecule, as is shown in the figure on this page.



A, an element, oxygen

B, a compound, water

C, a mixture of oxygen dissolved in water

Diagram showing how elements, compounds, and mixtures differ. The dots and the smaller circles inside the larger circles represent atoms in molecules. The small circles inside the water molecules (B) represent hydrogen atoms; the dots, oxygen atoms. Can you explain these diagrams?

A molecule is the smallest part of a substance that can exist by itself. No molecule is large enough to be seen even with the most powerful microscope.

*Sometimes two or more elements combine to form a *compound*. Thus, when hydrogen is burned in oxygen, the compound water is always formed. In this case, the atoms of hydrogen and oxygen have united to form molecules of water. Each of these molecules contains two atoms of hydrogen and one of oxygen. Also, when carbon, such as coal or charcoal, is burned in oxygen, carbon dioxide is always formed. In this case, the atoms of carbon and oxygen have united to form molecules of carbon dioxide. Each of these molecules contains one atom of carbon and two atoms of oxygen. Similarly compounds can be made to unite with other compounds to make still more complex compounds.

Every molecule of water is exactly like every other molecule of water.[2] And every molecule of carbon dioxide is exactly like every other molecule of carbon dioxide. No two different substances contain exactly the same combinations of atoms in their molecules. Therefore the number and kinds of atoms in the molecule of a given substance determine what the substance is.

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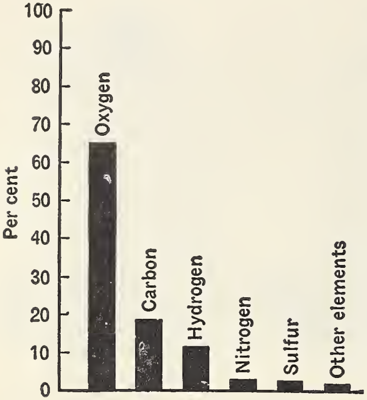
[1] Each atom is made up of one or more positive protons and one or more negative electrons. New facts about the structure of atoms are constantly being discovered by scientists. You will find more information about molecules and atoms in a textbook of physics or chemistry, and in magazine discussions of recent investigations.

[2] Recent investigations show that so-called "heavy water" molecules exist. These are of great scientific interest; and though they need not now be considered, some students may wish to find what recent textbooks in chemistry have to say about them.

Sometimes elements and compounds exist together without uniting to form new compounds. They are then said to be a *mixture.* A common mixture is air, nearly four fifths of which is the element nitrogen, and about one fifth the element oxygen. It contains also small amounts of four other kinds of materials: (1) rare elements, such as argon and neon; (2) compounds, such as carbon dioxide, ammonia, and water vapor; (3) nonliving dust particles, such as soot and soil; (4) living dust, such as bacteria, yeasts, molds, and microscopic animals. Other common mixtures are water in which air is dissolved, and ocean water, in which common salt and various other substances are dissolved. No two portions of a mixture, such as air, would necessarily contain molecules all of the same kind. But two portions of an element or a compound would.



The relative per cent of the elements composing protoplasm. What per cents, respectively, are carbon, nitrogen, and sulfur? What elements are included in "Other elements"?

Organic and inorganic matter. Nobody yet knows what life itself is. Many scientists have attempted to find out by analyzing protoplasm. But attempts to analyze it have always killed it. Chemists have learned, however, what substances compose protoplasm. They have found it to be made up chiefly of the elements carbon, hydrogen, oxygen, nitrogen, and sulfur. It contains also small quantities of the elements phosphorus, potassium, calcium, magnesium, iron, and several others. These elements are known to be combined in compounds. Some of these compounds, like water and carbon dioxide, are simple, having few atoms in their molecules. Others are exceedingly complex, containing in their molecules thousands of atoms. Most of the compounds in protoplasm, however, are composed of various combinations of the four elements carbon, hydrogen, nitrogen, and oxygen.

*Having learned what substances compose protoplasm, many scientists have attempted to make protoplasm. They have always failed. They have succeeded in building up in their laboratories many of the compounds found in living things, but there their success has ended. They have failed in organiz-

Galloway

Men and dog team of Admiral Byrd's first south-polar expedition. What objects in the picture are organic and what are inorganic? What objects are composed of protoplasm?

ing the compounds so that a living thing has resulted. The compounds existing in protoplasm are organized in such ways as to carry on life. For this reason animals and plants are called organisms, and their parts which perform certain necessary work are called organs. Living material and its products, together with dead animal and plant material, are called *organic matter*. All other matter, of whatever sort it may be, is called inorganic matter. Because they are so large a part of organic matter, compounds of carbon, oxygen, and hydrogen are called organic compounds. One great branch of chemistry, known as organic chemistry, is devoted to the study of such compounds.

Self-test. 1. Name six respects in which living things differ from nonliving things. Explain each.

2. In the test at the top of the following page match each item under *B* with one item under *A*.

A

a. Organic
b. Element
c. Phosphorus
d. Mixture
e. Atom
f. Molecule
g. Oxygen
h. Inorganic
i. Hydrogen

B

1. A colorless gas which causes rapid burning
2. Pure water
3. Smaller than any cell but larger than an atom
4. The general name for the ninety-two simple substances
5. A dead tree
6. A living tree

3. Which of the following are elements, which compounds, and which mixtures: lemonade, iron, lead, smoke, lean beef, wood, wet sand, air containing much water vapor?

4. Which of the following are organic, and which are inorganic substances: gold, hair, marble, milk, ground-bone fertilizer, a leaf, manure, living dust, nonliving dust, wood, glass?

WHAT ARE SOME IMPORTANT CHEMICAL AND PHYSICAL PROCESSES WHICH ARE RELATED TO LIVING THINGS?

Oxidation. The process by which substances combine with oxygen is called oxidation. The most familiar and common examples of oxidation are the burning of fuels such as wood, coal, and gasoline. Oxidation of food materials similar to the burning of fuel is taking place constantly in all living things, as will be shown later. Such oxidation, however, is slow as compared with the burning of fuels. But in all cases oxidation is accompanied by a release of heat energy, and usually also by a release of some other form or forms of energy, such as light energy, and the energy of motion.

Physical and chemical changes. All organic and most inorganic substances are constantly undergoing changes. These changes may be (1) in form; (2) in state, that is, from a solid, a liquid, or a gas to one of the two remaining states; or (3) in composition.

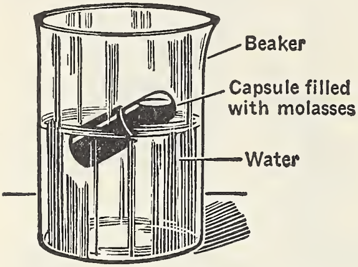
*When a substance is changed merely in form or state, but not in the composition of its molecules, it is said to undergo a *physical change*. Thus cutting meat into pieces small enough to go into one's mouth is an example of physical change, because the meat is still meat. When water is changed into ice or steam, it has undergone a physical change, because it has been changed in state. But its molecules have not been changed in their composition. Therefore it is still water.

*Whenever a substance is changed in composition, so that it is no longer the same substance, the substance is said to have undergone a *chemical change*.

What physical and chemical changes are illustrated in these four pictures?

In a chemical change the molecules are made to contain different numbers and kinds of atoms from those which they contained before the change. Thus the burning of fuel, the digesting of food, and similar changes which constantly go on in protoplasm are chemical changes.

Osmosis. Let us imagine that two gases, carbon dioxide and hydrogen, are put into a closed vessel together. Carbon dioxide is much heavier, volume for volume, than air. Hydrogen is lighter, volume for volume, than any other gas. Hence the carbon dioxide would fall at once to the bottom of the vessel, pushing the hydrogen to the top. If, however, the two gases are left undisturbed, they will in time become equally distributed throughout the vessel. Similarly, if two liquids which are capable of mixing are put together into a vessel, they will in time become equally distributed. Such mixing of gases or liquids is known as *diffusion.* Diffusion is explained as being due to the rapid motions of the individual molecules. These motions cause the molecules in time to become equally concentrated in every portion of the container.



How is osmosis illustrated here?

A process somewhat similar to diffusion may take place through the moist membranes of animal and plant cells. This process is called osmosis.[1] An experiment will help you to understand this process.

Experiment 5. What happens when different liquids are separated by a moist membrane? Secure from your druggist the largest empty capsule he has. This should be at least an inch long. Partly fill the capsule with molasses or sirup, and then drop it into water, as in the figure on this page. The capsule represents a plant or animal cell, the molasses in it represents protoplasm, and the water represents fluids around the cell. After about fifteen minutes examine the capsule. How have the contents of the capsule changed?

The results of this experiment may be explained thus: At first the molecules of water were more highly concentrated—that is, there were more water molecules per cubic inch—outside the capsule than inside. At the same time the molecules of sugar were more highly concentrated inside the capsule than outside. Therefore, as a result of their constant and rapid movements in all directions, the molecules of water tended to pass through extremely small holes in the membrane from the outside, where they were more highly concentrated, to the inside. There was a similar tendency for the sugar molecules to travel from their point of greater concentration, inside the capsule, to a point of lesser concentration outside the capsule. *Osmosis* may therefore be defined as the process by which liquids and gases travel through moist membranes from a point where their molecules are more highly concentrated to a point where their molecules are less highly concentrated. The increase in pressure caused by osmosis is called *osmotic pressure.*

In this experiment the molecules of water and of sugar were going through the membrane at the same time and in opposite directions. The sugar molecules were larger and also moved more slowly than the water molecules. Hence the capsule gained water molecules more rapidly than it lost sugar molecules. Consequently it became filled. If, however, the process could have been allowed to proceed long enough, without destroying the capsule, the molecules of sugar and of water would finally have become of equal concentration on both sides of the membrane. There would then have been equal numbers of both water molecules and sugar molecules passing constantly into and out of the capsule.

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[1] It will prove helpful to follow the practice of comparing the explanations of scientific terms in the text with the definitions of these terms in the Glossary.

Self-test. 1. The burning of wood in air is an example of *respiration.*

2. Tearing paper is an example of *physical* change.

3. Heating water is an example of *chemical* change.

4. Water enters plant tissues by the process of *oxidation.*

5. The breaking up of water into hydrogen and oxygen is an example of *chemical* change.

Self-test on Important Biological Terms. Explain in your own words the terms in the following list, and illustrate each with an example, an original one if possible. Consult the Glossary when necessary.

cell
cell theory
chemical change
compound
diffusion
element
function
inorganic matter
mixture
organ
organic matter
osmosis
oxidation
physical change
protoplasm
tissue

Self-test on Biological Principles. Explain and illustrate the meaning of this biological principle: "The cell is the unit of structure and function of all organisms."

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Can you state any reasons why tissues in different kinds of living things can never be exactly the same?

2. Explain why a vegetable stew is a mixture. How does concrete illustrate both a mixture and a compound?

3. The air over great cities is somewhat different from the air over country districts or over desert or lake regions. Explain.

4. How many examples of physical and chemical changes occurring in nature can you name in three minutes?

5. Will dried fruit, such as prunes, swell more when cooked with sugar or when cooked without sugar? Explain.

Exercises on Scientific Attitudes. 1. The names of Matthias Jakob Schleiden (1804–1881), a noted German botanist, and Theodor Schwann (1810–1882), a German physiologist, are always considered together because together they contributed the cell theory. Although they worked separately, they were fast friends and discussed their discoveries and conclusions together. Their work, especially that of Schwann, had great influence later upon the work of Pasteur and Lister. Which of the scientific attitudes (presented on page 624) are illustrated by the work of Schleiden and Schwann? (Consult an encyclopedia for additional facts about these men.)

2. Which of the scientific attitudes is illustrated by the sentence beginning on line 3, p. 33? by the second paragraph, p. 33?

Special Report. 1. Bring to class samples of the elements sulfur, phosphorus, and iron; and of the compounds potassium nitrate, sodium nitrate, potassium chloride, and phosphoric acid or calcium acid phosphate. Look up in textbooks of chemistry and of agriculture the importance of these substances to plants and to men and animals.

2. Keep a small notebook with you and for a week record interesting physical and chemical changes that you observe taking place (*a*) during your biology class periods; (*b*) about you while going to and from school; (*c*) in any industries or activities you may see or engage in, such as repairing streets or roads, preparing milk for sale, gardening, or taking care of passengers and freight at the railway depot; and (*d*) in the things you do for recreation, such as playing in team games, working with your hobby, and going on hikes. Make the report to your class in a series of bulletin-board displays, in the form either of lists of the physical and chemical changes or of a series of sketches or of drawings of the kind indicated on page 444.

3. In this chapter only a brief mention could be made of the important work of Hooke, Schleiden, and Schwann, but the achievements of these great scientists are worthy of a much more extensive discussion. Prepare, therefore, a report to be given in class or before the Science Club upon one or all of these men. Include in the report items which make clear (*a*) the character of the man, including especially any interesting anecdotes you may be able to find which indicate the kind of person he was; (*b*) the way in which he experimented or otherwise made his scientific discoveries; and (*c*) the difficulties he had to overcome in obtaining his results or in getting other scientists to accept them. Indicate how he used the scientific method (see page 625) and also point out any incidents in his life that illustrate the possession or the lack of scientific attitudes (see pages 624–625) on his part or on that of others. Consult encyclopedias and books on the history of biology, such as Locy's *Biology and Its Makers.*

CHAPTER IV

The Struggle to Live

Questions This Chapter Answers. 1. How is the sun the source of all energy? · 2. How do plants and animals compete with one another for energy? · 3. What is the energy cycle? the matter cycle? · 4. What are independent and dependent plants? · 5. Why do most animals and plants need to be complex? · 6. What is meant by "division of labor"? What is its importance? What are its social implications? · 7. What are some means of protection which animals and plants possess? · 8. What is meant by "the balance of nature"? · 9. In what ways does man upset the balance of nature?

HOW ARE LIVING THINGS ENGAGED IN THE STRUGGLE TO LIVE?

The sun the source of all food energy. Energy is the capacity to do work, that is, to move or to cause some other object to move. All living things are constantly using energy. They are constantly transforming or changing food energy into heat energy and the energy of movement. A few animals and plants, such as glowworms and certain fungi, transform food energy into light energy. A few tropical fish, as the electric eel, transform food energy into electrical energy.

The sun is about ninety-three million miles from the earth. It is constantly radiating[1] light, heat, and other forms of energy in every direction. Of this energy the earth receives only a very small fraction—about one part in every two billion. Without this small fraction of the sun's radiant energy, however, no life of any sort would be possible on the earth.

Plants and animals cannot live on this radiant energy just as it comes from the sun. It must be transformed, or changed, into food energy. Men and other animals cannot make their own food from the sun's energy. They must find it already made. They must secure and eat other animals or plants or their products. Green plants, however, can use the radiant energy of the sun in the manufacture of their own food. Thus every green plant is a food factory. All the food in the world which all the plants and animals consume in order to secure the energy they need was made by green plants. Therefore all the food in the world may be traced finally to the sun.[2]

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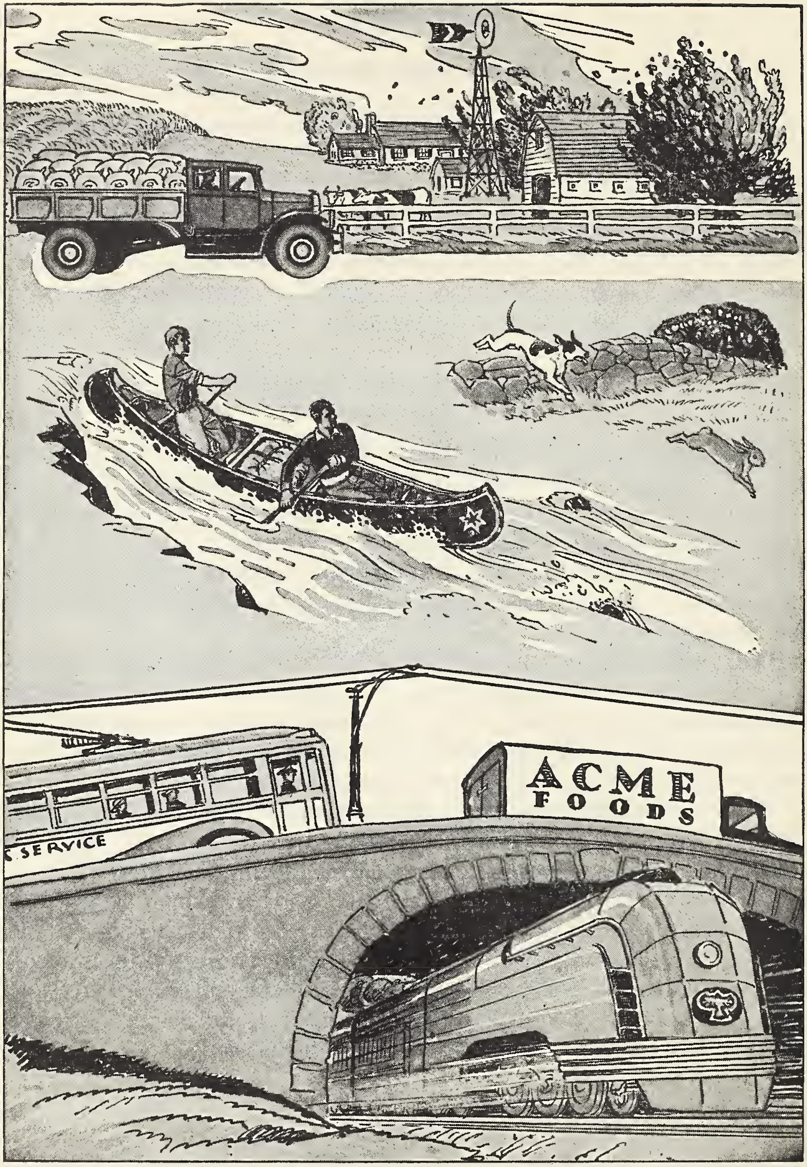
[1] *Radiate* (rā'dĭ āt): to send out in all directions. *Radiation* (rā dĭ ā'shŭn): the act of radiating. *Radiant* (rā'dĭ ănt): relating to radiation.

[2] It is true that some of the radiant energy from other stars than our sun reaches the earth, but this star-shine is so faint as not to be considered a source of radiant energy on the earth. It is true also that some of the simplest organisms use certain elements and certain simple compounds which are not made by green plants, but these exceptions to the general statement are few.



How many examples of different forms of energy can you find in this picture?

If the contents of the stomach of a whale were examined, it would probably be found to contain fishes. If the stomachs of these fishes were studied, they would be found to contain smaller fishes or other aquatic[1] animals. If those in their turn were studied in the same way, they would be found to contain still smaller aquatic animals or plants. Finally we should discover that the smaller animals had been feeding upon microscopic animals and plants that are found in countless numbers and varieties near the surface of the oceans. All these plants are able to use the radiant energy of the sun to make food. Therefore we may say that the whale gets its food indirectly from the sun.

Suppose we eat a piece of beefsteak as a source of our needed energy. The animal from which the steak was obtained got its energy from eating green plants or their seeds. These plants used the sun's radiant energy to make food. Hence we may say again that we get our beefsteak indirectly from the sun.

*And so it is with everything that we or any other living creatures eat. All energy stored in the form of food may finally be traced to the radiant energy of the sun.

Life a constant struggle. *The total amount of energy which is available to all the creatures on the earth is limited. There is not plenty for all. Consequently there is a constant struggle for survival. Every animal or plant is forced to compete with others of its kind and with living things of many other kinds. Every individual must somehow succeed in securing energy enough to maintain life. Usually this can be done only at the expense of some other animal or plant.

Man is constantly in conflict with other animals, such as rats and insects, and with plants, such as molds and wheat rust, to prevent them from reducing his precious stores of food to the point where he can no longer exist as comfortably as he wishes. Similarly all animals prey upon other animals or upon plants.

The constant struggle to secure energy goes on just as severely among plants as among animals, though it is not so likely to be observed. The green plants can make their own food, but in order to do so they must grow fast enough or high enough or broad enough to keep a sufficient amount of their green surfaces exposed to sunshine. The stronger ones, therefore, crowd out or shade and thus kill the weaker ones, or they take for their own uses materials in the soil that are necessary to the existence of other plants.

Social implications.[2] The biological principle "All organisms are constantly engaged in a struggle for energy" applies to man as well as to all other

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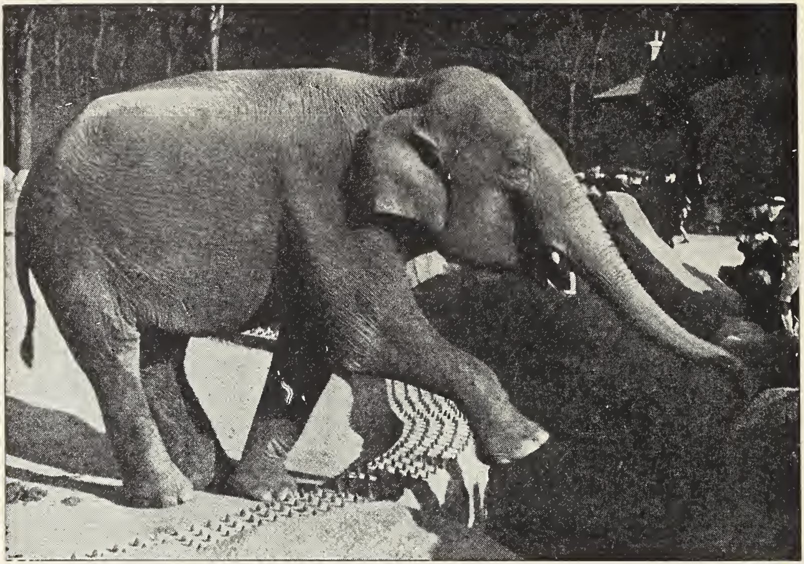
[1] *Aquatic* (ȧ kwăt′ĭk): living in the water or upon its surface.

[2] *Implication* (ĭm plĭ kā′shŭn): a thought that is conveyed indirectly.



Gendreau

Hartman

In what sense are these animals engaged in the constant struggle for survival? What biological problems which are now solved for them would these animals need to solve if they were wild?

organisms. During the Second World War Germany, Italy, Japan, and the other Axis nations invaded other countries largely for the purpose of securing more land upon which they could raise the food they need; of securing needed supplies of energy in the form of coal and petroleum; and of securing metals, drugs, and other natural resources.

This principle applies also to all people who work for a living. During most of their lives they engage in an intense effort to secure energy in the form of food, fuel, and the like; or to secure money with which to buy energy. Employment is important chiefly because it provides a means of securing energy, without which human survival would be impossible.

The energy cycle.[1] Each kind of plant or animal strives to keep alive as long as possible and to thrive during its life as much as possible. To do this it must be able (1) to secure food, because food contains not only fresh supplies of energy, but also fresh supplies of materials with which to grow, and (2) to rebuild or replace injured and worn-out parts of its body.

*New energy which living things can use cannot be created. Energy can only be changed from one form to another. The green plants do not make new energy when they make food. They merely transform the sun's light energy and heat energy into another form of energy, namely, food, which they can use. In their own activities the living green plants are constantly transforming food energy into heat energy and the energy of movement. When they die or become prey to other creatures, this energy stored in their bodies is again transformed. Thus it is passed on and on from one plant or animal to another endlessly. But the energy is never destroyed. This constant transforming of one form of energy into another and from one living thing to another is called the energy cycle.

The matter cycle. *There is a matter cycle, similar to the energy cycle. The amount of matter available[2] is limited. No new matter can be made. No matter can be destroyed. It can only be changed. When a plant or an animal carries on any of its life activities, many of its cells are broken down. These must be replaced. Also, during the processes of growth and reproduction, new cells must be produced. The organism must secure from the available supply of materials those which it needs in building the protoplasm required for replacement,[3] growth, and reproduction.

If the available building materials become reduced, the number of living things must be reduced. Should the building materials become entirely

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[1] *Cycle* (sī'kl): a series of happenings or of stages of development that occur over and over, and always in the same order.

[2] *Available* (*ȧ* vāl'*ȧ* bl): ready at hand.

[3] *Replacement* (rē plās'mĕnt): act of putting back; state of being restored.

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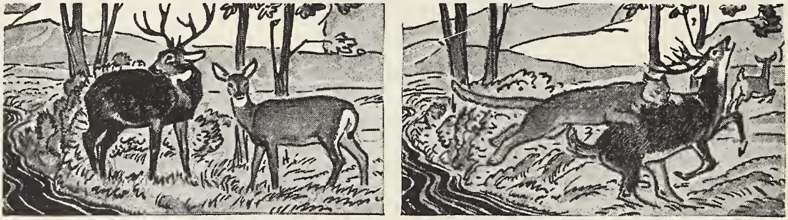
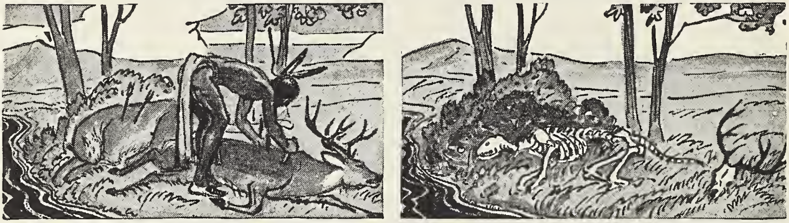


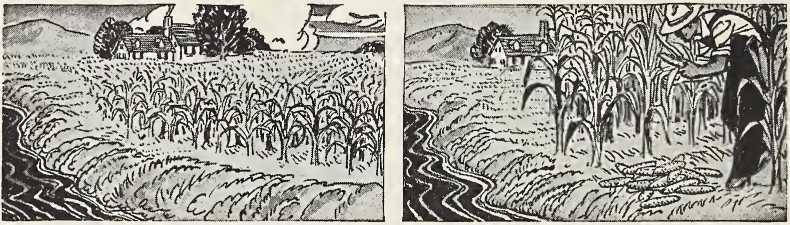
Scene two hundred years ago

Same location five minutes later,



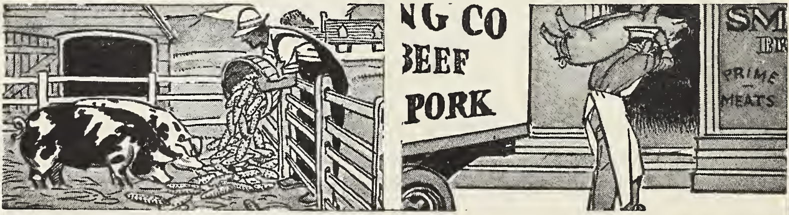
Same location fifteen minutes later

Same location two years later



Same location last July

Same location last September

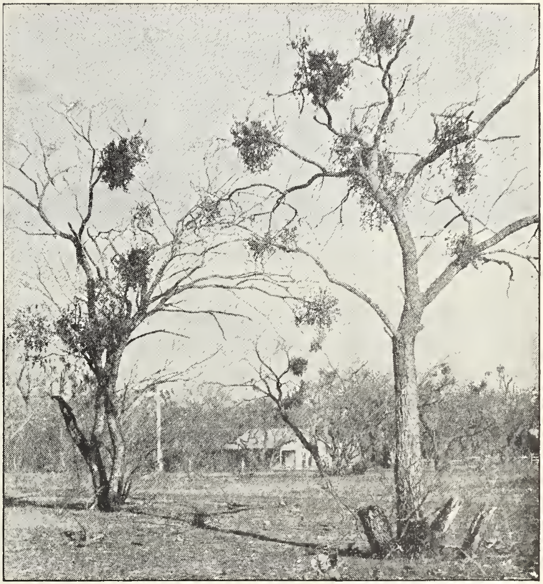


Same farm in November

Same pigs in December

Self-test on Biological Principles: Define in your own words *energy cycle* and *matter cycle*. Explain how this series of drawings illustrates both exhausted, no new animals or plants could begin life. Also, the living animals and plants would die almost at once because the matter needed for growth and for the replacement of worn-out parts would be in the bodies of the animals and plants already living.

Death, therefore, is necessary to continued life, because whenever a plant or an animal dies, not only its store of energy but also its matter is again made available to be used again and again by other animals and plants. Thus, while every individual animal or plant lives only a relatively short time, life itself continues from age to age.



United States Forest Service

Mistletoe growing on oak trees. Can you name any other plant parasites?

Independent and dependent plants and animals. *Living things which make their own food are called *independent organisms.* Those which cannot do so are *dependent organisms.* Thus only the green plants are independent. Only they of all the living things are able to manufacture their own food.

There are some flowering plants, such as mistletoe and dodder, which are dependent because they can make only part of the food they need. These plants live as parasites.[1] All plants which are not green—for example, the mushroom, wheat rust, and bread mold—are dependent. Such plants are either parasites or saprophytes. A *saprophyte* is a plant that secures its food from the bodies of dead plants and animals. Unlike a parasite, a saprophyte never feeds upon living things. All animals are dependent because they must always secure their food energy from living or dead animals and plants. Some animals, like some of the plants, are parasites.

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[1] See the Glossary.

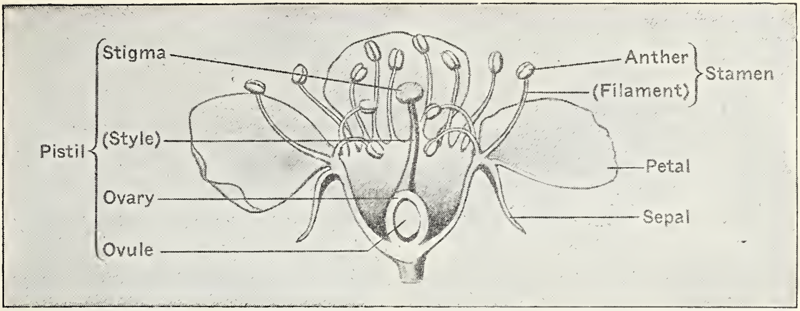
A dandelion plant. How does the dandelion plant illustrate division of labor?

Many structures for many uses. Most living things are complex. They have many different structures which serve them in securing matter and energy. A few examples will illustrate this statement. Let us examine first a living seed plant. Any plant will do, for we shall study now only general characteristics. A dandelion plant can usually be found for such a study. The whole plant has four main parts: the roots, the stem (which may be difficult to distinguish from the root), the leaves, and the flowers. Each of these parts is necessary to the existence of a flowering plant. Its roots serve to keep it anchored. These roots must be deep enough and strong enough to prevent the plant from being pushed over or pulled out of the ground by the wind or by animals. The roots must be sufficient in number and must extend sufficiently far to secure from the soil the water and the other matter which the plant needs.

The stem of the dandelion is very short. But, like the stems of other seed plants, it is long enough and of the right sort to hold the leaves up to the sun's radiant energy. The leaves of the dandelion manufacture its food. The bigger the plant grows, the more leaves it must have to provide the food which it uses for its own growth and which it stores in its seeds and roots.

The dandelion, like every other seed plant, has flowers. This particular plant which we are examining could live its life without flowers. They serve no useful purpose in so far as its own existence is concerned. But without flowers it could not produce seeds. Hence it could not produce new dandelion plants. Without reproduction its kind would soon cease to exist.

Division of labor. *The dandelion, then, is a complex organism. Every part has a certain definite and important service to render to the plant as a whole. Each part has a size, shape, and structure which permits it to do its



The parts of a typical flower. In what part of this flower do you think the seed is formed?

special work. Usually any one part does only its own work, because other parts of the plant perform the other necessary functions. But if the plant as a whole is to survive and if its kind is to survive, every part must be able to do its share well. Thus the plant is an association of parts. The activities of such an association of parts of a living thing, each part doing its own special work and contributing to the plant or animal as a whole, are known as *division of labor.*

Experiment 6. How do the parts of a typical[1] flower illustrate division of labor? You may use any simple flower, such as apple, tulip, lily, petunia, violet, buttercup, or morning-glory. Look near the stem for the outer row of green leaf-like parts, the *sepals.* (If you are using a tulip or a lily, these parts are colored like the next row.) All the sepals together make up the *calyx.* The brightly colored *petals* are the most conspicuous parts of most flowers. How many petals has your flower? Is the number the same as the number of sepals? When the petals are spoken of together, we call the structure a *corolla.* Inside the corolla find the *stamens*, which are slender stalks with knobs, called *anthers*, at the tip. How many stamens are there? Touch an anther with your finger. The powder which comes off is *pollen.* Examine some of the pollen under a microscope. Make a sketch showing the shape. In the center of the flower is the *pistil.* By comparing your specimen with the figure on this page, identify the *stigma*, *style*, and *ovary*, which are all parts of the pistil. With a knife or razor blade cut across the ovary. The small round structures are *ovules*, which may develop into seeds. Make a diagram which will show the parts of a flower as you find them in the flower you are studying.

Each of these parts, or structures, of the flower has its own special function, that is, its purpose to serve or its work to do. We shall study the functions of these flower parts in more detail later. Can you suggest from your own observations the functions of any of the parts of the flower?

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[1] *Typical* (tĭp′ĭ kl): characteristic, illustrating a type.

Let us see how division of labor is illustrated by some complex animal, such as a dog. If a dog were kept anchored to one spot, as the dandelion is, he would soon die. He needs to roam in search of food, water, and other necessities. His legs are a means of locomotion.[1] He has bones in his legs, which hold his body up from the ground. He has two pairs of legs, each pair somewhat different from the other and each doing somewhat different work. The dog has other bones which hold up his head. The head has its special organs—ears, eyes, and nose—with which he can locate food and detect the presence of enemies.

We could point out a great many more structures and parts of the dog, each of which performs some definite and necessary service for the animal. Each is a member of the association of parts which is the whole dog. Each performs its special service in the division of labor.

In division of labor certain organs share their particular labors with similar ones. Thus we have two hands and two eyes. We could, of course, continue to live if we lost one hand or one eye. But in such a case the remaining hand or eye must do the work of both. A person has been known to live for years after his stomach had been removed. In such a case, however, the portion of the work which is ordinarily done by the stomach had to be taken over, as best it could be, by other organs. It happens rarely, if ever, that an animal or a plant is able to carry on its life work so effectively after having lost some structure as when its equipment was complete.

Practically all organs share in the division of labor. So do also the parts of organs. It is easy to understand this statement when one recalls that an organ is composed of different kinds of tissues, each made up of certain cells capable of doing certain kinds of work.

Social implications. Division of labor takes place in every family and in every community, just as it takes place in every complex organism. Each member of a family has certain work which he alone does and which contributes to the good of the whole family. Moreover, every community has its lawyers, its carpenters, and its other workers in all the different callings. Each of these does a special kind of work which is useful or essential to the community as a whole. It would be easy to show in a similar way how division of labor takes place throughout a whole state, a whole nation, and even the whole world.

Self-test. 1. The source of the energy used by living things is the __?__.

2. All organisms are constantly competing with one another for the available *light.*

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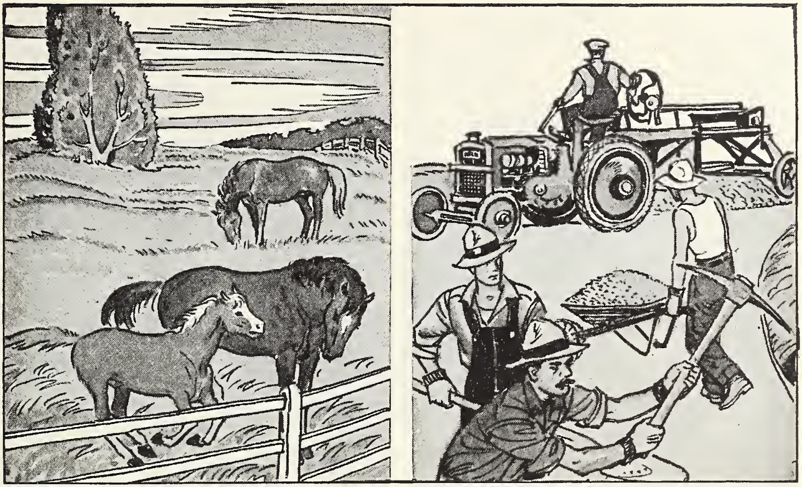
[1] *Locomotion* (lō kō mō′shŭn): the act or power of moving from place to place.



Division of labor. Compare division of labor in a complex animal, such as a horse, with that of a gang of men at work. (See "How to Study," pp. x–xi.) **Self-test on Biological Principles:** Can you give two original examples of the principle "Division of labor takes place in all complex organisms"?

3. Energy cannot be either *created* or destroyed; it can only be *transformed*, or changed, from one *form* into another.

4. Matter cannot be either *created* or destroyed; it can only be transformed, or changed, from *one* form into another.

5. If no plants or animals should ever die, the time would finally come when *few* new plants or animals could be produced.

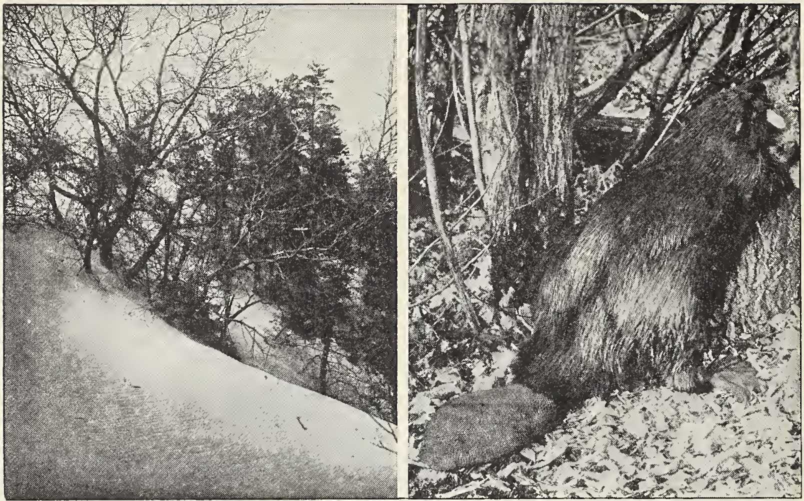
6. A flea which lives on a dog's back is a *saprophyte.*

7. A toadstool is a saprophyte, and hence is an example of *an independent* plant.

8. All green plants are *dependent* because they can make their own food.

9. A tree is an example of a *simple* living thing.

10. Teeth with which to chew food, and stomach and intestines with which to digest it, are together an example of --?--.



National Parks Bureau of Canada

Which of the types of enemies are illustrated by this drifting sand (near Lake Michigan) and this beaver?

HOW ARE LIVING THINGS PROTECTED AGAINST THEIR ENEMIES?

Kinds of enemies. Every living thing has its enemies. These enemies are not always other animals or plants. An enemy is anything which makes life difficult or impossible. An enemy is therefore anything (1) which takes some or all of a plant's or an animal's stores of energy; (2) which cuts off or reduces its sources of energy; (3) which kills it at once or which injures it so that it can with difficulty continue its normal life; (4) which changes its habitat in such a way that it cannot continue to live there.

One does not need to search far in order to find evidences of the constant struggle of living things against their enemies. A study of any weed patch or park will no doubt furnish examples of the four types of enemies which have just been named.

Protective adaptations of plants. Plants have various structures which protect them and thus help them to survive. Such structures are sometimes called protective[1] adaptations.[2] Thus the tender structures in the stems of plants are protected by the tough outer covering. In plants like corn and bamboo this outer covering is a tough rind-like structure. In plants like the trees and bushes the outer stem structures are bark. The bark of the sequoia trees of California sometimes attains a thickness of more than three feet and serves for protection not only against ordinary injuries and enemies but also against forest fires.

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[1] *Protective* (prō tĕk'tĭv): giving protection.

[2] *Adaptation* (ăd ăp tā'shŭn): a structure or a behavior which adapts, or fits, a plant or animal for living successfully in its environment.

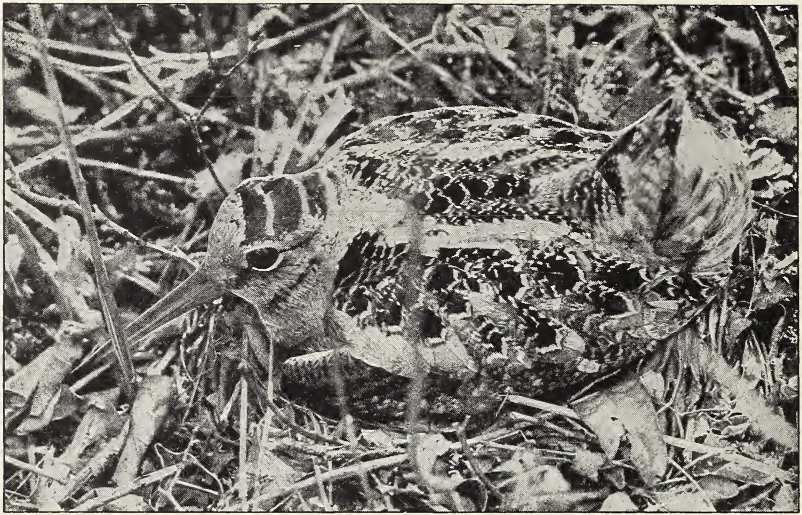
Some plants have developed thorns which serve to protect them from animal enemies. In such plants as the acacia and the nettle these thorns have developed from stem structures. In other plants, such as some roses and nearly all cactuses, the thorns have developed from leaves. Some plants have juices which make them poisonous or unpleasant in flavor. Some are protected from certain animal enemies by the unpleasant odors given off by their leaves or flowers.

Protective adaptations of animals. Like plants, animals have various protective structures. Those which are most likely to be noticed are the hard coverings, that is, the exoskeletons, of insects or of such animals as crayfish, crabs, and lobsters; or the shells of snails or of "shellfish," such as starfish, sea urchins, clams, oysters, and barnacles. Animals like ourselves, which have skeletons of bones, are likewise protected to a great extent by these skeletons. The skull is a sort of box which surrounds and protects the delicate brain. The ribs form a kind of crate, enclosing the lungs, heart, and other organs. The hip bones form a sort of half-open box (pelvis) which protects delicate organs.

The means which serve animals for protection include both those of fighting and those of resisting or avoiding the attack of enemies. It must be remembered that the enemies of any animal may include not only other living things but also various weather conditions, such as changes in temperature, storms, and other factors. The protective means which aid animals in survival may be grouped in a few general classes. Some of these classes have to do with structures. Others are concerned with the products of the structures.

1. *Structures serving directly for offense or defense.* The stings of bees and the teeth of dogs are examples of such structures. Protective structures, such as the human skull, belong also in this class, as do exoskeletons, such as those of insects, and shells, such as those of the oyster and the snail.

2. *Adaptations of skin.* Any sort of skin serves to some extent as a protection against accidental injuries and against such enemies as changes of temperature, bacteria, and biting or stinging animals (for example, certain insects). The skin of the rhinoceros is thick enough to serve as armor even against small bullets. Such special adaptations of skin as scales, fur, and feathers are especially important factors in the survival of many creatures.



Lynwood M. Chace

A woodcock on her nest. Her chances to survive are here increased both by her protective coloration and by an adaptation of behavior. What is this adaptation of behavior? **Special Report:** Camouflage (artificial protective coloration) in the Second World War

3. *Artificial exoskeletons.* Some of the simplest animals build artificial shells around their bodies by cementing together tiny particles of sand. The larva of the caddis fly, which lives on the bottom of streams and is a food much liked by fish, protects its body with an artificial shell of very small pebbles or twigs.

4. *Adaptations for speed.* Animals like deer, rabbits, pheasants, and trout are often able to escape from their enemies because they can run, fly, or swim faster.

5. *Adaptations of protective resemblance.*[1] Animals which are colored or shaped so as to look like parts of their environments have better chances of escaping their enemies than have those which are not so colored or shaped. Certain animals, such as the chameleon and the tree frog, change in color to correspond with that of the tree, rock, or other object upon which they happen to be resting.

6. *Products of specialized structures.* The skunk produces a fluid of such unpleasant odor as to cause other animals to avoid it. The octopus (see figure on page 458) when attacked is able to give off a black fluid which so clouds

[1] *Resemblance* (rē zĕm′blăns): a likeness.

the water that the animal can often escape unseen. The electric eel of the Amazon River is able to give a painful shock to an enemy near it in the water.

7. *Adaptations for producing a fierce appearance.* The harmless hognose snake when in danger flattens its head and hisses in a very threatening manner. The caterpillar of the puss moth sticks out two orange-colored "horns" when an enemy approaches.

8. *Adaptations of behavior and habit.* Some animals—for example, the common hognose snake and the opossum—often pretend to be dead when they know an enemy is near. The hognose snake lies on its back while "playing dead." If turned over, it immediately throws itself again upon its back with absurd haste. It seems very much alive in its effort to appear dead. Other animals, especially certain of the birds which nest on the ground, pretend to be injured in order to entice an enemy away from the nest. The mother bird flutters on the ground, apparently almost helpless, but just out of reach. She makes it appear that she can barely escape capture until she has lured her enemy to what she considers a safe distance. She then flies swiftly away.

Many animals are able to escape blows by dodging. It is amusing to see two bear cubs or two kittens boxing with each other. Still other animals—for example, some owls, squirrels, and rabbits—escape enemies by hiding in holes, in trees, or elsewhere. Others, such as foxes, owls, and raccoons, escape many enemies by hiding during the day and going about their activities only at night.

9. *Other adaptations.* A few animals escape detection because their characteristic odors are absent. The newly-born deer, for example, possesses no odor whatever. A dog with a keen sense of smell will pass within a few feet of the motionless fawn and remain totally unaware of its presence. Other animals, such as bees and rats, find safety in numbers by living together.

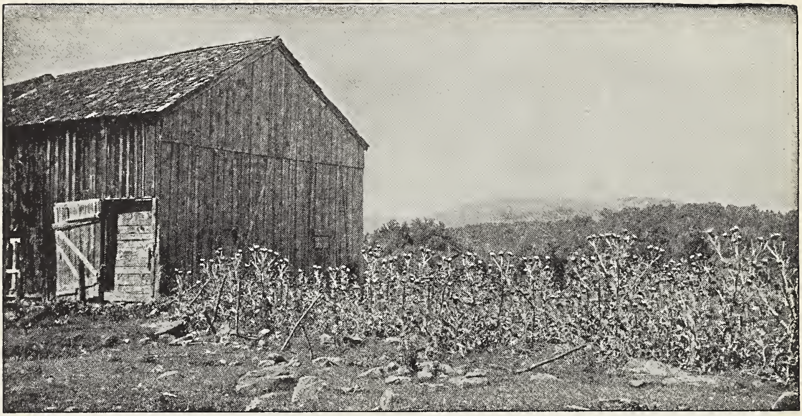
Self-test. **1.** Name four kinds of enemies which may make the survival of living things difficult.

2. *All* plants and animals have structures which serve for protection.

3. Select from the following phrases the one which does not belong with the rest: (1) artificial exoskeletons; (2) protective coloration; (3) ferocious appearance; (4) food and water; (5) extremely unpleasant odor; (6) spines and thorns.

WHAT IS MAN'S RELATION TO THE BALANCE OF NATURE?

The balance of nature. *When the animals and plants of a given region are left undisturbed for a long time, they finally establish a balance of life, or balance of nature. This expression means that the number of each kind



Thistles are well fitted to compete for energy. What evidence is there in the picture that supports this statement? How has the balance of nature been disturbed here? Would the balance of nature be restored if all these thistles were cut? Justify your answer

of plant or animal remains approximately the same. This number includes all that are able to compete successfully for food and other necessities with all the other animals and plants in that region.

Left to themselves and without man's interference, animals and plants rarely exterminate, or kill off, all the individuals of any kind. And when such exterminations have occurred long periods of time were necessary to accomplish them. When a new plant or animal is introduced into a region, it may increase very rapidly at first. But after a time, if man does not interfere, its numbers remain about the same from year to year. Thus, when the English sparrow was first introduced into this country, it thrived so well and spread so quickly to all parts of the country that it seemed likely soon to exterminate many of our native song birds. But now its numbers are scarcely changing. It has not exterminated any native birds. Therefore it is now finding its place in the balance of nature. The English starling is still increasing in numbers. It has not yet found its place in the balance of nature.

Unusually favorable conditions, as of food or weather, may cause a temporary increase in the numbers of certain plants or animals. Unusually unfavorable conditions may similarly cause a temporary marked decrease in their numbers. But when the unusual conditions end, the balance of nature is slowly established again.

Man upsets the balance of nature. The balance of nature is disturbed more often by man than by all other agents, or factors, combined. Primitive man of some twenty or thirty thousand years ago probably lived much like the other animals. Hence he did not then disturb the balance of nature much more, if indeed any more, than they did. But when he developed sufficiently to become a farmer,—that is, when he first began to raise plants for his own use instead of searching the fields and forests for them,—he upset the balance of nature. He not only made available to the insect and plant enemies of his crops an increased supply of food, but he also concentrated his food supply in one place, with the result that the insects could find abundance without traveling far for it. Similarly other animals were attracted by his crops and by his domesticated[1] animals. When he learned to store food during winter, this practice likewise invited visits from animals that desired the food.

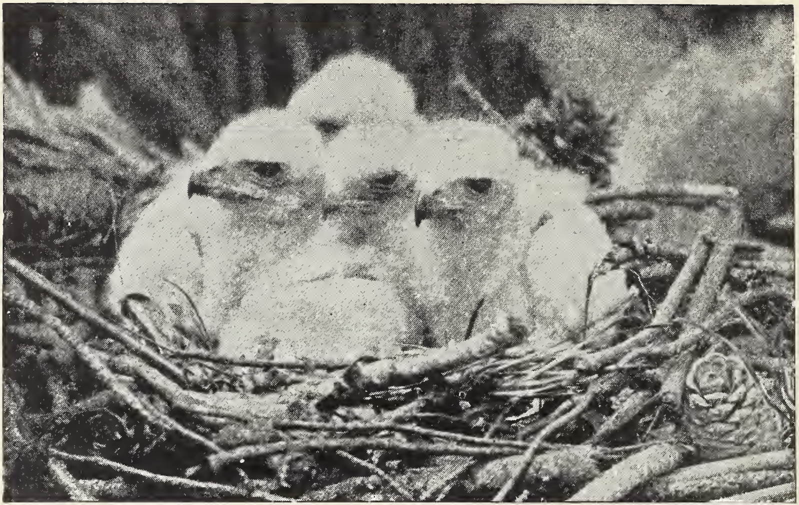
The result of these various human activities was a great increase in the numbers of plants and animals which were competing with man for his energy supply. Furthermore, as man cleared the ground for his crops, he provided not only more space for weeds, but also conditions favorable to their growth. As these weeds were vigorous of growth, they often choked out his crop plants by shading them. They also took for their own uses materials in the soil which the crop plants needed.

Man disturbs the balance of nature by searching the world for new plants and animals for his uses. When he takes a plant from its original habitat, he does not usually take also its enemies. Without these enemies the transplanted plant or animal sometimes multiplies so rapidly in the new environment as to become a pest. The water hyacinth, a beautiful plant, got a start in this way in the inland waters of some of the Southern states. There, without its usual enemies, it multiplied so rapidly as to hinder navigation in certain rivers.

Man disturbs the balance of nature by introducing pests with his commerce. The European corn-borer, the Japanese beetle, the Mediterranean fruit fly, and many other pests were thus brought into this country undetected, with commercial products. None of these insects is so serious a pest in the regions from which it came as it is in the United States, because in its older habitat it has a sufficient number of enemies to keep it in control. But here, without these enemies, it has multiplied so rapidly as to become a serious threat to certain food crops.

Man disturbs the balance of nature by spreading plant and animal pests with his travel. Insects and seeds often are carried from one part of the

[1] *Domesticate* (dō mĕs'tĭ kāt): to tame a wild animal or to make a wild animal or plant



Lynwood M. Chace

These young Cooper's hawks belong to an undesirable species. Explain

country to the other on radiator shields and other parts of an automobile, by airplanes, by trains, and in camping equipment.

Man disturbs the balance of nature by killing species harmful to himself. Years ago the farmers in certain states found that hawks were preying upon their chickens. Not knowing that some hawks are useful, they passed a bounty law, offering money for every hawk killed. They hoped thus to exterminate the birds. Hawks of both useful and harmful kinds were killed in great numbers. The farmers did not know then that in killing the hawks they were disturbing the balance of nature by removing an important enemy of the field mice and other small animals which attack grain crops. Soon, with the number of hawks diminished, those animals multiplied so rapidly as to be a serious threat to the wheat crops. The farmers then repealed the bounty law on hawks and passed another law providing a fine for anyone who killed a hawk. The surviving hawks found unusually large numbers of small animals, and with this abundant food supply the birds multiplied rapidly. Consequently in a few years the balance of nature was restored.

Man disturbs the balance of nature by hunting, trapping, and fishing for food, profit, and pleasure. In pioneer days game animals and food fishes were abundant. But the white man when unrestrained by law soon changed this condition. Sturgeon were caught in the Columbia River by the ton and, after their eggs had been removed, were left to rot on the river banks. Song birds were killed in enormous numbers for their feathers, which were put on women's hats. Elk were killed for their teeth. Many wild things were killed for no reason except the pleasure derived from killing them. These are only a few of many examples which might be given of the wanton destruction of wild life.

Man attempts to restore the balance of nature by conservation. Realizing that the rapidly vanishing wild life must be protected, national and state governments have passed laws for its protection. Several societies have been organized for the same purpose, and many private citizens have given their time and money generously in the same cause. The various means adopted for the conservation of wild life are discussed in Chapter XIV.

Social implications. Unlike most other animals, man protects and helps the weak and the sick, and tries to feed and care for all members of his kind. For these and other reasons the human population in many regions increases beyond the point where the resources are sufficient to support it comfortably. In densely populated parts of some countries, such as China and India, many people live their whole lives with only just enough food to sustain them. These people are likely to be in a more or less weakened condition. Therefore they easily become the victims of plagues or less serious diseases. Also, if for any reason there is an unusual lack of food, a famine results and great numbers of people die. Many deaths from famine and disease tend to restore the balance of nature as far as the people of these countries are concerned.

Self-test. 1. If the animal population in one of the national parks remains unchanged for many years, it is *probable* that the balance of nature has been established there.

2. List the various ways in which man upsets the balance of nature.

3. Man has introduced many types of *conservation* as a means of preserving wild life.

Self-test on Important Biological Terms

adaptation
balance of nature
dependent organism
division of labor
energy cycle
independent organism
locomotion
matter cycle
parasite
saprophyte
survival

Self-test on Biological Principles. How would you explain these principles to someone who had not studied biology?

1. The plants and animals in a given environment depend on one another.

2. All plants and animals are engaged in a constant struggle for energy.

A. M. N. H.

This huge "dragon" of Komodo and others like it are protected by the Dutch government, which owns Komodo, an island east of Sumatra and Java, on which these animals live. They are of no use to man for food and are exceedingly ferocious. For what reasons do you think they are protected?

3. Protective adaptations are an aid to survival.
4. Division of labor in living things is an aid to survival.
5. The plants and animals of a given locality tend to establish a balance of nature.

Social Implications of Biological Principles. 1. How does division of labor function in your home-room or your assembly at school? in presenting a class play? in playing football or basketball?

2. Can you give a specific example from the Second World War of a nation that attacked another chiefly for the purpose of securing energy?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Give an original example illustrating (1) energy cycle; (2) matter cycle; (3) division of labor.

2. Why are not artificial shelters, such as muskrat and beaver lodges and a man's house, listed among the classes of protective adaptation?

3. A toad has poison glands in the skin of its back. Should a dog eat the toad, the dog would die. Do you consider this adaptation a means of protection for the toad? Explain.

4. Do you know any ways in which man's use of domestic animals disturbs the balance of nature?

5. Did Robinson Crusoe disturb the balance of nature on his island? Explain.

6. Describe several adaptations which you have observed in plants; in animals. How are these of advantage to the plant or the animal in the struggle for energy?

7. Under which of the four classes of enemies would you place each of the following: a manufacturing company which by emptying waste products into a river makes the water unsuitable for fish; a sparrow which snatches a worm from a robin's beak; a big tree which shades a smaller one; a stream which washes out a tree; a hailstorm which breaks down small plants and knocks branches from trees; a dandelion growing in a lawn?

8. Under which of the classes of protective adaptations does each of the following belong: the chrysalis or cocoon of an insect; a growling dog with bared teeth; a white ptarmigan (grouse) in the snow; the armor of a crocodile; a knight in armor; the spurs of a rooster; a bird flying when another animal approaches; the odor that a shrew gives off and that drives away many larger animals which otherwise would eat the shrew?

9. How does the Second World War relate to the struggle for existence?

10. In what ways has the Second World War disturbed the balance of nature? In what ways can it be restored in the postwar period?

Project 1. To collect examples of protective adaptations. Keep a record of every sort of protective adaptation, such as those described on pages 59–61, which you observe that animals and plants possess or use. List the examples you find under the various kinds, or types, of adaptation described.

Reference Books

Locy, W. A. *Biology and Its Makers.* Henry Holt and Company, Inc., New York.
Sharp, L. W. *Introduction to Cytology.* McGraw-Hill Book Company, Inc., New York.
Wilson, E. B. *The Cell in Development and Heredity.* The Macmillan Company, New York.

Motion-Picture Films[1]

Animal Camouflage. Films of Commerce, New York.
How Living Things Find a Home on the Earth. De Vry, Inc., Chicago.
How Nature Protects Animals. Erpi Picture Consultants, New York.
Killers (the Battle for Life Series). Bell and Howell, New York.

[1] The films listed at the end of each unit are only a few excellent ones of many available. Consult *Educational Film Catalog,* The H. W. Wilson Company, New York.

UNIT II · PLANTS AND

Whenever we hear or see the term *food factory*, we are likely to think of some great manufacturing plant which produces such things as breakfast food, canned vegetables, canned milk, or meat products. Also, we are likely to think of such factories as located within great cities. Such factories, however, do not really manufacture food. They merely use ready-made foods for their raw materials, and change those ready-made foods into other forms of food.

Where, then, are the real food factories—those that make food from materials which are not already food? We should not look in the manufacturing districts of great cities for them. Relatively few are to be found in cities, and such as are located there are chiefly in the parks and suburbs. By far the greater number of the real food factories are to be

THE WORLD'S FOOD SUPPLY

found in the country. Indeed, if we were to take a walk through the woods or fields or a country garden, we should see them everywhere. We should be likely to step on hundreds or perhaps even thousands of them, though we might not recognize them as food factories.

The real food factories are among the most important objects in the world. If all of them should suddenly stop their work, the struggle for survival, which has been discussed in Unit I, would soon cease. There would soon be nothing and nobody left to carry on the struggle to live. Man, as well as all other living things on the earth, would be able to survive only until the food now available was consumed. Then life on earth would cease. The real food factories are, of course, the green plants. How green plants manufacture food will be discussed in this unit.

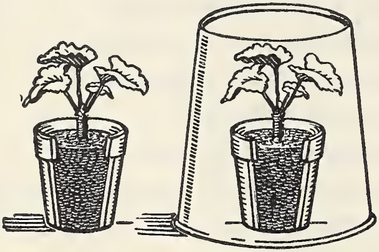
CHAPTER V

Competing for Light

Questions This Chapter Answers. 1. How does photosynthesis depend on the forms and arrangements of leaves? · 2. How are plants adapted to varying amounts of sunlight? · 3. How does competition for radiant energy affect the forms of plants? · 4. How are the habits and structures of the early flowering plants in dense forests adjusted to their life under the trees? · 5. How do trees adjust themselves to varying amounts of sunlight? · 6. How are deciduous and evergreen plants adapted for photosynthesis?

HOW ARE VARIOUS KINDS OF PLANTS EQUIPPED TO SECURE ENERGY FROM THE SUN?

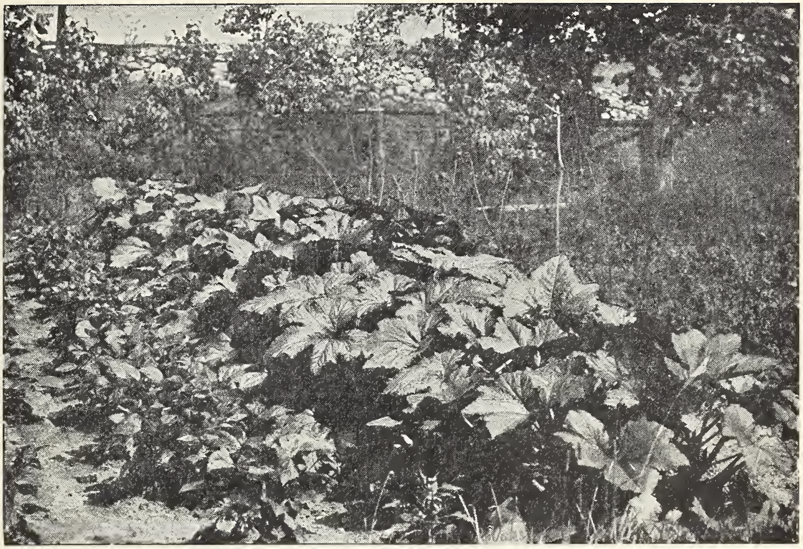
Green plants make food. Every living thing faces the problem of securing food. Most animals move about in their search for food, and eat either other animals or plants. Plants are usually fixed in one place. They are either rooted in the ground or attached to some support. They must, therefore, secure their food from their immediate environments. Green plants can make their own food out of substances which, by themselves, are not foods. No other living things can do this, with the exception of a few small animals which possess the same food-making material, called chlorophyll, that is found in all green plants. All living things are, therefore, entirely dependent on green plants for the manufacture of their food supply.



Exercise on Scientific Method: Why is it better scientific method to make the test with several leaves from each plant than with only one from each?

Ordinary plants are green because chlorophyll is green. Chlorophyll is able to transform the energy of sunlight into food energy.

Experiment 7. Is more food produced in green leaves after they are placed in bright sunlight or when they are in darkness? Place two vigorous plants, such as geranium, coleus, or primrose, side by side in the bright sunlight. Cover one of the plants with a pail or other covering which will completely exclude the light, as in the figure on this page. After several hours take several leaves from each plant. Mark the leaves so that you will know from which plant they were taken. Place all the leaves in a beaker or test tube half full of alcohol, and then stand the beaker or test tube in hot water. Keep the water hot. The warm alcohol will remove the chlorophyll from the leaves. When the leaves are as nearly white as they will be-



A squash vine. How is this leaf arrangement adapted to securing light energy?

come, remove them from the alcohol and pour over them a solution made by dissolving iodine crystals in either water or alcohol. If starch is present in any of the leaves, they will turn blue-black. Answer the question asked at the beginning of this experiment.

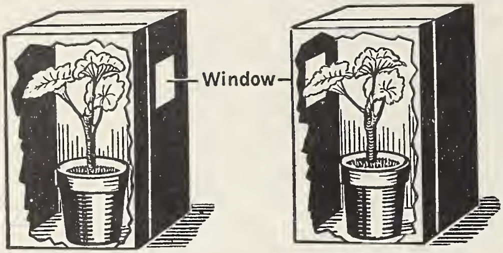
In this experiment you were practicing two of the elements of scientific method: using controls[1] and isolating[2] the experimental factor.[1] What conditions were the same with all the leaves? What condition was different? This was the experimental factor. The leaves which were kept in the dark were the controls. Explain. Why was it better to experiment with but one experimental factor, that is, with the presence or the absence of light?

Reaching for the light. *One of the chief problems of a plant is to secure a sufficient amount of sunlight to enable its chlorophyll to make as much food as it needs. A study of any plant-covered area will show that there is a great variety in the types of leaves and stems which various plants possess. These differences in the forms and positions of the leaves are adaptations for the securing of light. Indeed, leaves that are not well lighted cannot make much food. Therefore plants suffer for lack of sufficient supplies of food if too many of their leaves are shaded.

[1] See the Glossary.

[2] *Isolate* (ī'sō lāt): to put by itself, or away from others of its kind.

Experiment 8. Do plant stems tend to grow toward or away from light? Select two small potted plants of the same kind and as nearly alike as possible. Secure two large boxes of the same kind, such as shoe boxes. Cut two windows of the same size in opposite sides of the two boxes. (See the figure.) Place one plant in each box and place both the boxes in equal lighting in a window. Keep the boxes closed except when watering the plants. Do not change the positions of the plants. After a week or so the plants should indicate the answer to the question at the beginning of this experiment. What is the answer? State it in a complete sentence.



What was the value of the check experiment following Experiment 8?

Perform a check experiment thus: After the two plants have grown sufficiently so that there is no doubt concerning the answer to the question at the beginning of Experiment 8, turn both plants halfway round. Continue the experiment as before. Is the result of this experiment the same as that of Experiment 8 or different from it?

In this experiment you were using controls and isolating the experimental factor (see "Elements of Scientific Method," presented on page 625). Why were two plants used instead of one in this experiment? Each served as a control for the other. Explain. How many factors were identical with both boxes? Which was different? This was the experimental factor.

Types of leaf arrangement. *If you carefully examine almost any plant, you will see that the leaves are arranged in such a way that most of the surface of each leaf is exposed to sunlight at some time during the day. Very seldom does one leaf entirely cover another. The stems usually grow longer as the plant grows. The result is that the leaves become separated so that they do not shade one another too much. Also, the upper leaves of most plants usually have shorter leaf stalks and are smaller than the lower ones, and therefore do not shade them completely. The leaf stalks and leaves of climbing plants that grow upon rocks, fences, or walls twist about so as to present a broad surface to the light. Ivy growing on a building illustrates this habit of growth. The branches of trees usually grow in such a way as to permit as much light as possible to strike the leaves.

The arrangement of leaves on a plant stem or on one of the branches varies with the kind of plant. Thus the leaves of the horse-chestnut and the maple are in pairs, with one leaf on each side of the stem and with each pair at right

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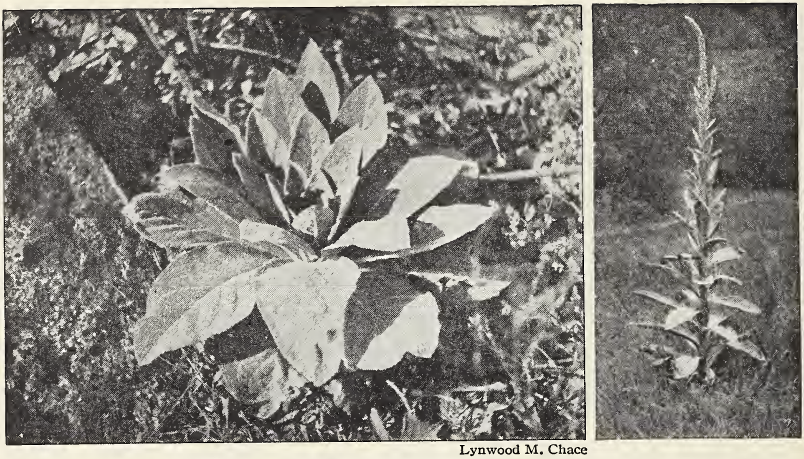
Two climbing plants, Virginia creeper (left) and poison ivy (right). How do these climbing plants secure light energy?

angles to the pair immediately above or below it. The leaves of the apple have a spiral arrangement, like that of a coiled spring or a circular staircase.

The leaves of plants which grow close to the soil, such as the dandelion and the plantain, are arranged in a rosette pattern. In these plants the stems of the upper leaves are shorter and more nearly upright than those of the lower leaves. Also, the upper leaves themselves are shorter and less broad than the lower ones. The leaves are so arranged on the very short stem of the plant that the upper ones fit into the spaces between the lower ones. The rosette arrangement keeps the leaves close to the earth. Thus it not only reduces the danger from excessive drying by winds but also helps to protect the plant from rapid changes in temperature.

Rosette plants are often biennial; that is, they require two years to complete their life cycle. They make much food the first year and store the surplus food in the underground stems or roots. By means of this stored food the plants may make earlier and more vigorous growth in the second year. In the second year they send up stems on which flowers develop and produce seeds, as shown on the next page. These stems bear leaves which in form seem to be quite different from those that compose the rosette. A close inspection, however, shows that the arrangement of the leaves on the stem is practically the same as that in the rosette. The long stem now serves to separate the leaves. Thus it prevents higher leaves from shading lower ones and thus depriving them of direct sunshine.



Lynwood M. Chace

Mullein plants. Left, first year, a typical rosette plant; right, second year. Compare the two leaf arrangements shown here. (See "How to Study," p. ix)

Adaptations to varying amounts of sunlight. While a leaf must have sufficient light in order to do its work properly, too much or too intense light is harmful. Some plants, such as iris, grow in such a way that the broad surfaces of their leaves receive the direct morning and afternoon sunlight, while only the edges of the leaves are presented to the intense light of midday. In other plants, such as the sensitive fern and the rosin-weed, the leaves may turn on their stems. Thus they avoid being exposed to too much light.

The intensity of sunlight at midday is much greater than in early morning or late afternoon. It is much greater in summer than in early spring. It is also much greater at the top of a forest or in an open meadow than under the forest trees. An exposed rock or sandy surface is much more intensely lighted than a shaded cliff or a deep ravine. Yet plants in all these regions are at work, securing and using the sun's energy.

In early springtime, before the forest trees have developed their leaves, the forest floor may have a display of early flowers of many kinds. Spring beauty, bloodroot, anemone (or windflower), hepatica, violet, buttercup, and many others appear in flower soon after the snow is gone. Some of these produce flowers before their leaves appear. Such plants have clear green leaves which are usually thin and delicate. They thrive and grow rapidly in the milder light of early spring. Seeds ripen in a few days or at most in a few weeks. By the time the forest trees have produced their year's crop of leaves, and the more intense summer sunlight has come, these early spring plants have manufactured abundant supplies of food and have stored the surplus in their underground stems or roots. The leaves of most of these plants die at this time. Consequently we do not see these plants again until the next spring. Then the stored food of the preceding year provides the energy which enables the plant to produce spring flowers and its new crop of leaves.

Many other plants, such as ferns and trilliums, are able to live only in the shade of forest trees throughout the summer. Many "shade-loving" plants have large leaves, which present broad surfaces to the dim sunlight.

The seedlings[1] of forest trees themselves may start to grow under the milder light of the dense forest, and may secure enough sunlight to permit them to live until they are several years old. In fact, the seedlings of many kinds of forest trees cannot begin to grow except under the protection of the shade of the dense forest. This same shade, however, prevents the continued growth of the seedlings into mature trees. It is only when an opening is made by the removal of the older trees that the young trees can secure enough light to permit them to become large trees.

Competition for light. A tree growing in an open field or on a lawn has a well-rounded shape. Its branches begin only a few feet above the ground. The same kind of tree growing in a crowded forest has a very different appearance. It is tall and straight, with no living branches near the ground. These differences in form are due to the relative difficulty the trees experience in securing enough sunlight. The tree in the open has little or no competition from other trees. Consequently its lower branches can grow out beyond its higher ones and secure sunlight. The tree in a crowded forest, however, has a severe struggle for light. Its lower limbs, which become shaded, die and finally fall off, thus leaving a tall, straight stem.

Trees that have been injured often show remarkable ability to adjust themselves to the sunlight. One or more of the limbs of a fallen tree the roots of which remain in the soil may assume the shape of a tree and expose their leaves to light as the whole tree did before.

Young forest trees which, in spite of severe shading, are able to survive for many years may become twenty to thirty feet tall and not more than an inch or two in diameter. They bear leaves only at their tops or at the outer ends of their slender branches because there is severe competition not only among the trees but among the leaves and buds on the same branch. They have barely enough leaves to permit them to live, not enough to allow them to prosper. The tree trunks are so slender that sometimes they would not support the weight of leaves and branches if they stood in the open where

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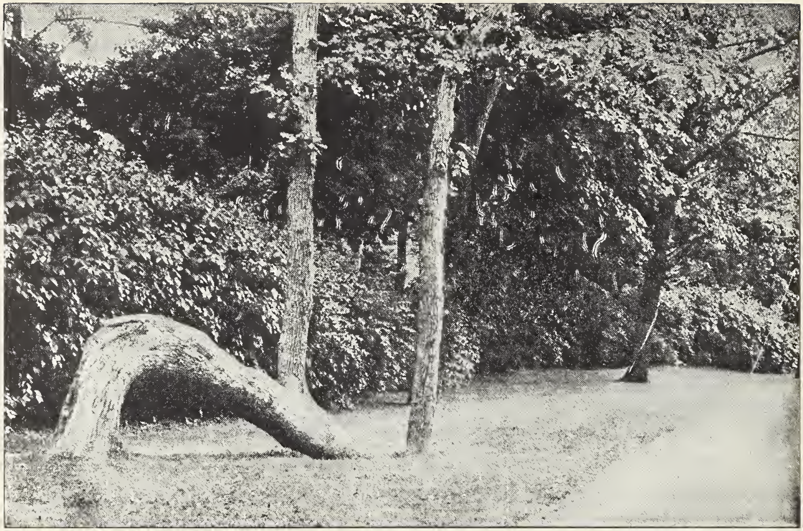
[1] *Seedling* (sēd'lĭng): a young plant which has recently developed from a seed.



United States Forest Service

Explain how this tree limb developed to look like a tree

strong winds could strike them. A maple tree which was growing under such dense forest shade was found to be twenty feet and four inches tall; yet it had leaves on its upper three feet only. When cut, the trunk near the ground was found to be one and a quarter inches in diameter. It was more than thirty years old.

Deciduous and evergreen plants. Trees and shrubs can be conveniently divided into two groups, deciduous and evergreen. Deciduous plants are those that shed their leaves every fall and grow a new crop every spring. Deciduous plants of the Temperate Zones include maples, elms, and fruit trees. Such plants are dormant[1] during the months in which they are without leaves. They then live on the food which they made and stored during the preceding season.

A deciduous tree or shrub usually produces its new crop of leaves in a very short time. This rapid growth has survival value because it enables the plant to make the best use of the sunshine during the few months in which it can make food.

Evergreen plants are those that are never without green leaves. Such plants include hemlocks, spruces, firs, pines, yews, and cedars, and even

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[1] *Dormant* (dôr'mănt): in a state resembling sleep. *Dormancy* (dôr'măn sĭ): the condition of being dormant.

Deciduous and evergreen trees. Compare the deciduous trees on the left with the evergreen tree on the right. (See "How to Study," p. ix)

smaller plants, such as rhododendrons, laurels, and some kinds of holly. They grow new leaves and shed their old ones, a few at a time, during the entire year. They may even retain some leaves for several years before shedding them.

The leaves of most evergreen plants of the Temperate Zones are narrow and rigid. In the pines and their relatives these leaves are called needles. New leaves of evergreens are less commonly observed than those of deciduous plants because they are added to the green leaves which the plants already possess, while the new leaves of deciduous plants appear upon branches that were bare. Evergreens are never dormant, because they continue their food-making throughout the year.

In tropical countries, just as in the Temperate Zones, trees produce new crops of leaves regularly. The new leaves are less conspicuous, however, because, in the tropics, so many more of the shrubs and trees are always green. Plants which in the Temperate Zones are deciduous may in the tropics be green throughout the year.

Self-test. 1. In order to survive, *every* green *plant* must have its leaves so arranged that they are sufficiently exposed to the sunlight.

2. Most of the delicate flowering plants carry on the process of food-making for a *greater* part of the year than other plants.

3. Intense sunlight prevents the growth of the seedlings of *some* kinds of trees.

4. If a green plant has too *few* leaves, it will starve to death.

5. A branch with too *few leaves* may die.

6. *Deciduous* trees make food during the entire year.

Self-test on Important Biological Terms

deciduous evergreen seedling

Self-test on Biological Principles. How would you explain these principles to somebody of your own age who had never studied biology?

1. Not only different plants, but also different parts of the same plant, compete with one another for the sun's energy.

2. The forms of all green plants are adapted for carrying on photosynthesis.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. What survival values are found in the rosette pattern of leaves which enable certain plants possessing it to live in exposed rocky and sandy soil, where most other plants cannot survive?

2. Why do plants which live in the shade of forest trees usually have broad and thin leaves?

3. In planning your home gardens it is important to arrange the planting so that the rows of vegetables will run north and south rather than east and west. What advantages are there in such an arrangement?

Project 2. To secure examples of various arrangements of leaves. Find, in the woods, fields, garden, or greenhouse, plants the leaf arrangements of which illustrate the types described in this chapter. Photograph, diagram, or describe each of these plants so as to show the arrangement of its leaves. Can you find any plants of which the leaf arrangements seem distinctly different from those described in this chapter?

CHAPTER VI

The Plant and Some of Its Problems

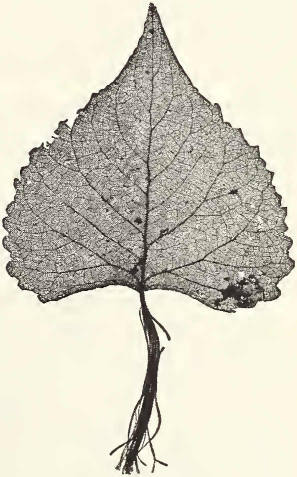
Questions This Chapter Answers. 1. In what respects is a green plant like a factory? · 2. What are the important structures of a leaf and what are their functions? 3. What materials are used by the green plant in making food? · 4. What structures within the leaf are directly concerned with food-making? · 5. How is energy secured for use in the manufacture of food? · 6. What uses are made by the plant of the food which it manufactures? · 7. What are the nature and the importance of transpiration? · 8. What causes water to rise in plants? · 9. What changes occur in deciduous and evergreen plants before winter arrives? · 10. What are some other important leaf functions besides photosynthesis and transpiration?

HOW IS A LEAF FITTED TO MANUFACTURE FOOD?

The green plant a manufacturing organization. In some ways a green plant is like a large manufacturing organization. Such an organization has separate divisions which manufacture desired products from raw materials. It has its own transportation system to carry raw materials to the factories and also to carry finished products from them. It has its warehouses in which the surplus manufactured products are stored until needed.

In a green plant each leaf is a separate factory engaged in the manufacture of food. Certain tissues which are in the leaves, branches, stem, and roots permit the circulation of liquids. These tissues compose the transportation system. Through these tissues raw materials are carried to the leaf factory, and the manufactured products are carried away. The various parts of the plant where surplus food is stored are the plant's warehouses.

Inside the leaf factory. *The principal parts of a leaf are the flat, expanded portion, or blade, the veins, and usually a leaf stem, called the petiole. Some plants, like corn or grass, do not have petioles on their leaves. Instead the leaf blade is attached directly to the stem of the plant.



This cottonwood leaf was placed in water where one-celled animals (*Euglena*) ate the chlorophyll tissue but not the upper epidermis or the veins. What are the functions of the epidermis and the veins?

The manufacture of food takes place in the blade. The transportation of water and other materials to the leaf factory and of surplus food from it is

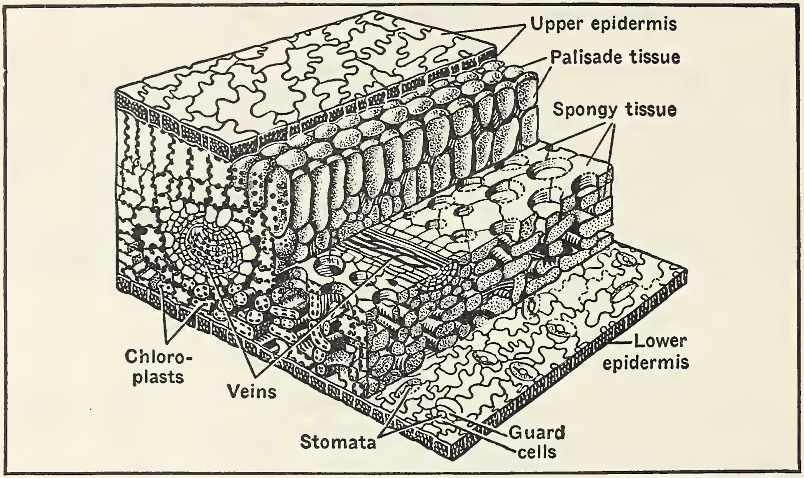


Diagram of a leaf with portions cut away to show the structures. Explain the functions of the leaf structures shown in this diagram

carried on through the veins and the petiole. The veins also serve to strengthen the leaf and to hold it in shape.

*The cross section of a leaf shows a number of important parts in detail, as will be seen in the figure on this page. The outside layers of cells compose the epidermis.[1] In parts of the epidermis are special openings called stomata.[2] Each stoma is guarded by two cells, called guard cells. Under certain conditions of moisture these guard cells may change their forms so as to open or close the stoma. Thus they control the amount of air which may enter and pass out of the leaves.

Under ordinary conditions, the guard cells are filled with water and stand out like two well-filled balloons. Then air can pass freely through the stoma. But when the weather is very dry or hot, the guard cells do not contain so much moisture. Then their walls are no longer extended. Instead they fall together like two partly filled balloons, thus partly closing the stoma. Air cannot then pass so easily into or out of the leaf. Under these conditions, the water vapor within the leaf cannot escape so readily. Thus the guard cells, in regulating the size of the stomata, help to keep the plant from wilting by losing too much water.

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[1] To the Teacher. The pupils may be referred to Experiment 4, p. 31 (epidermis of an onion).

[2] Stoma (stō′mȧ), plural stomata (stō′mă tȧ): openings in the surfaces of leaves. Sometimes the words *stomate* and *stomates* are used as the singular and plural, but *stoma* and *stomata* are preferred.

Each stoma opens into a large space among the inner green cells of the leaf. These spaces permit the food-manufacturing cells to secure carbon dioxide from the air and to give off oxygen as a waste product into it.

Experiment 9. Are there more or fewer stomata in the upper epidermis than in the lower epidermis of a lily, geranium, maple, elm, or other common leaf? Carefully peel off the epidermis only, from the upper and lower sides of the leaf. Mount the two specimens on a microscope slide and examine them under the low power of the microscope. Make a complete statement or make diagrams giving the results of your observations. Examine the stoma and its guard cells under the high power and compare what you observe with the figure on page 80. Make sketches of any types of stomata which seem to be different from those shown in the figure. What advantage does the plant derive from having its stomata distributed as you observed them to be?

Experiment 10. What is the appearance of the chlorophyll bodies, or chloroplasts, in a leaf cell? Secure a leaf of *Elodea* or a leaf from a moss plant. Such a leaf is so thin that one can easily see through it. Mount the entire leaf by putting it in a drop of water on a microscope slide. Put a cover glass over it. Examine it first with the low power of the microscope and then with the high power. Find a cell where the green bodies, that is, the chloroplasts, show clearly. What is the shape of a chloroplast? Approximately how many are there in the cell? Can you discover any movement of the chloroplasts?

*The large inner cells of the leaf usually have two kinds of arrangement. Beneath the upper epidermis is a layer of long cells, called palisade cells. In the interior of the leaf the green cells are loosely arranged, like the tissue of a sponge. This tissue is therefore called the spongy tissue of the leaf. The palisade cells, and to a somewhat lesser extent the cells of the spongy tissue, are the chief food-making parts in the leaf factory.

The palisade and spongy tissues are not wholly green, but they contain so many chloroplasts that the whole leaf appears green. There are no chloroplasts, however, in the veins or in the spaces between the cells of the spongy tissue. Moreover, there are usually few or none in the cells of the epidermis, except in the guard cells. The chloroplasts are the bodies in which the plant's food is made.

The transportation system within the leaf. When a leaf is carefully pulled from the stem or a branch, one may usually observe the broken veins, or vascular[1] bundles. In many kinds of plants the scars that are left after the

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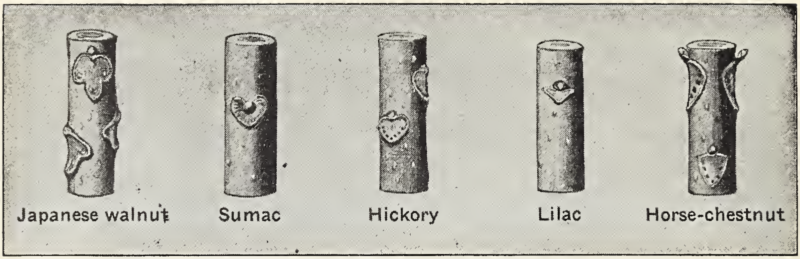
[1] *Vascular* (văs′kū lẽr): made up of tubes and ducts, or vessels, and having to do with the circulation, or flow, of blood or sap.



Leaf scars. Can you determine where the veins, or the vascular tissues, continued from the stem into the leaf?

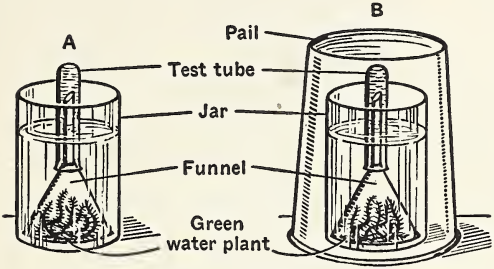
leaves are shed show the ends of the vascular bundles. The veins of the leaf extend through the petiole and connect with the transportation structures in the stem and root. In a cross section of a leaf, shown on page 80. the midrib, or middle vein, and other veins are seen to consist of cells which have thick walls and small cell spaces between the walls. These cells, which in cross section appear relatively small, are really like long tubes. These groups of cells are called vascular bundles, or fibrovascular bundles, both because the cells are in bundles, or fibers, and because they are used in the circulation of sap.

The food-making process. The chief raw materials used by the plant in food-making are carbon dioxide and water. The water is taken into the roots from the soil by osmosis. It is carried up through the stem into the veins of the leaf. From the veins it passes into the air spaces around the cells inside the leaf, and is then absorbed into each cell. The carbon dioxide enters the leaf directly through the stomata, and passes into the air spaces within the leaf. It is dissolved in the film of water which surrounds each cell, and then passes by osmosis into the cell. Carbon dioxide and other gases dissolved in soil water may enter the plant to some extent through the roots.

Experiment 11. Are portions of leaves which contain no chlorophyll able to manufacture food? Place in bright sunlight a potted plant with variegated leaves—for example, a spotted begonia, a coleus, or a variegated geranium. After a few hours pick several of the leaves. Test for starch, as in Experiment 7. Do the white parts of the leaf, which contain no chlorophyll, have starch? Do the green parts contain starch? From the experiment should you conclude that the plant does or does not need chlorophyll in order to manufacture starch?

As a check experiment, place a growing geranium or other potted plant in the dark and allow it to remain there for several days until its leaves are white or yellow. Remove some of these leaves and see whether you can remove the chlorophyll from them, as in Experiment 7. Do they contain chlorophyll? Now place the plant in bright sunshine for a few hours. Test some of the leaves for starch. What results do you obtain from these tests? What conclusions, therefore, do you draw from this experiment?

What is the value of a check experiment? In this experiment the white spots on the leaves were controls. Explain.



Sunlight is the experimental factor. Explain

Experiment 12. Does a green plant when placed in bright sunlight give off oxygen? Select vigorous green water plants of the same kind and as nearly alike as possible. Fill two jars with water, each to the same depth. Then place a plant in each jar and cover each with a funnel. Over the top of each funnel place a test tube full of water as in the figure on this page. Cover one of the jars completely with a pail or black cloth, so that it is entirely in the dark. Place both jars side by side in the bright sunlight. After several hours examine the test tubes over each plant to see whether either or both contain a gas. If so, the gas is oxygen.

As a check experiment, repeat the experiment exactly as at first, except that you expose the plant in vessel *B* to the sunlight and keep that in vessel *A* in the dark. Make a complete statement answering the question at the beginning of this experiment.

Answer the following questions to show how you were using the scientific method: Why was it necessary to have all conditions except one as nearly identical as possible with both the experimental plant and the control (the covered plant)? What was the advantage in repeating the entire experiment with the experimental factor applied to plant *B* and with plant *A* as the control?

If no gas was found in the test tube above either plant, did this prove that neither plant gave off oxygen? Suggest one or more hypotheses (see the Glossary) which might explain why no oxygen appeared, even though it might have been produced.

Using the sun's energy. Only a small part of the sun's energy which strikes the earth is absorbed by chlorophyll. Nevertheless that small part directly or indirectly supplies the energy which all living things use in carrying on all their activities.

*The chlorophyll uses the sun's radiant energy to produce chemical changes in the substances within the plants. Thus, inside the leaf, carbon dioxide and water are combined to form sugar and starch.

VACATION-TIME BIOLOGY

SPRING *vacation on the desert! We thrilled at the thought! There would be so much to see at that time. The desert flowers would be almost certain to be abundant.*

We found even more flowers, and more kinds of flowering plants in bloom, than we had expected to find. We had crossed the desert several times before, in winter, in early summer, and in early fall, but at those seasons had found it so dry that there was only scanty vegetation. We could not imagine flowers thick upon the desert. But the rains of late winter and early spring had brought about a vast change. Wherever we looked purple-red verbena, white and pink sand-dune primrose, yellow desert sunflower, and violet and bluish-purple wild heliotrope made especially bright patches of color. Their vivid beauty was matched by the yellow of the creosote bush and the red of the chuparosa.

Equipped with a desert-flower guide, we seized the first opportunity to accompany the nature counselor on one of his trips. We learned that the plants out on the desert differ considerably from those near the base of the mountain ridge which bounds the desert. They can live only in sand much drier than the mountain flowers can endure. The counselor told us that the kinds of plants which bloom near the mountains depend on whether relatively little or much rain has fallen during the winter and early spring. After seasons of little rainfall, the desert plants advance almost to the mountains. In very wet seasons, however, the mountain flowers advance for considerable distances into the desert. The seeds of both desert and mountain plants are, of course, present in this area every season. Which seeds are able to germinate and successfully carry on the struggle for existence depends on the amount of moisture in the desert soil.

We found many examples of adaptations for survival under difficult conditions. One especially interested us. We had supposed that plants always die if drifting sand exposes their roots or completely covers them. We learned, however, that with desert plants this is not always the case. If part or all of the root becomes exposed by the shifting of the sand, and another part of the plant remains covered or becomes covered, the exposed part develops a new stem, while the part under the sand develops new roots. If, moreover, the entire plant becomes covered, but not too deeply, it puts forth an unusually long stalk and thus frequently is able to lift its leaves into the sunlight.

[The colored illustration on the opposite page is copyrighted by Stephen H. Willard]

While man does not know how to make food by the use of chlorophyll, he does know how to produce many chemical compounds by combining other compounds or elements or by breaking up complex compounds. These processes involve chemical changes. If the changes are such that the new product is formed by combining other substances, the process may be called a synthesis. The process by which green plants make food by combining water and carbon dioxide is a synthesis. Light is used to supply the energy needed by the plant to make these substances unite. Therefore the process by which the chlorophyll in green plants manufactures food with the aid of the sun's energy is called *photosynthesis.*

Biologists and chemists have not yet found out what the first compounds are which the chlorophyll makes. A reason for this failure is possibly that these first compounds are changed very quickly into other ones. We know, however, that the first compounds are organic compounds, that is, compounds of carbon, hydrogen, and oxygen. We know also that grape sugar, which is somewhat like ordinary sugar, is formed, and that later starch and other organic compounds may be formed. Grape sugar and starch belong to the class of organic compounds called carbohydrates.[1]

In any manufacturing process there are usually by-products left over when the making of the chief product is completed. In the process of photosynthesis large amounts of oxygen are produced as a by-product. The oxygen passes by osmosis through the cell walls into the air spaces within the leaf and thence through the stomata to the outside. Thus oxygen, upon which all living things depend, is constantly being renewed as a result of photosynthesis.

We may explain the process of photosynthesis in this way:

$$\text{Chlorophyll} + \left\{\begin{matrix}\text{the energy}\\ \text{of}\\ \text{sunlight}\end{matrix}\right\} + \left\{\begin{matrix}\text{carbon}\\ \text{dioxide}\\ \text{from the air}\end{matrix}\right\} + \left\{\begin{matrix}\text{water}\\ \text{from}\\ \text{the soil}\end{matrix}\right\} = \text{sugar} + \text{oxygen}^{2}$$

Other substances which a plant uses. The water which comes into plants from the soil carries many substances in solution. Among these substances

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[1] *Carbohydrate* (kär bō hī′drāt): an organic compound made up of atoms of carbon, oxygen, and hydrogen, but usually differing from other organic compounds in having twice as many atoms of hydrogen as of oxygen, just as water has. Thus the chemical symbol of water is H_2O, which means that the molecule of water is made up of two atoms of hydrogen and one of oxygen. The chemical symbol of grape sugar is $C_6H_{12}O_6$, which means that the molecule of grape sugar is made up of six atoms of carbon, twelve atoms of hydrogen, and six atoms of oxygen. The chemical symbol of starch is $C_6H_{10}O_5$. Can you explain the meaning of the symbol of starch?

[2] We might express this statement in symbols, thus:

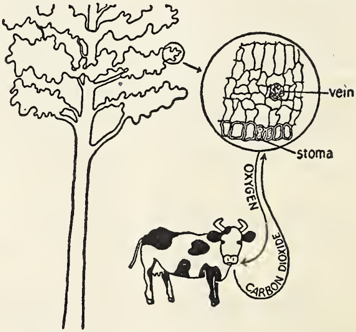
$$\boxed{\text{C}} + \overset{\text{Sunlight}}{\downarrow\downarrow\downarrow} + 6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2$$

are (1) organic compounds that have been left in the soil by the decay of dead plants and animals; (2) mineral compounds and nitrogen compounds; and (3) special plant-fertilizers that have been placed in the soil by farmers or gardeners. Still other compounds, some of which the plant cannot use, may enter the roots with the water which has dissolved them.

A potato plant. Can you explain how the potato plant stores excess food in its underground stems?

Making foods other than carbohydrates. In addition to making carbohydrates, green plants may make still more complex foods, called fats and proteins. The synthesis of fats and proteins requires neither sunlight nor chlorophyll. Also, these foods may be made by animals as well as by plants. They may be produced from carbohydrates by chemical processes in the living cells. Many of the substances secured from the soil are used by plants to produce proteins of various kinds.

Foods for use and for storage. Within the green leaves larger quantities of carbohydrates are made than the leaf is likely to need at once for its own nutrition and growth. The sugars that have been made are easily dissolved in the sap of the leaf. They pass through the cell walls by osmosis and reach the vascular tissues. Through these they pass downward to all parts of the plant. Some of these sugars may be used at once for food by any living part of the plant. Some may be used in making starches, proteins, or fats. These foods are not easily dissolved by cell sap and therefore may be stored. Many wild plants, such as violets, jack-in-the-pulpits, and forest trees, and some of our most important cultivated plants, such as the potato, corn, and wheat, store large amounts of carbohydrate food as starch. Nuts and seeds often contain large amounts of proteins and fats. Thus while the food is transported in the form of sugar, it is usually stored in some other form, though in some fruits it is also stored as sugar.



This is a drawing by a high-school student of biology to illustrate the oxygen–carbon dioxide cycle. Can you explain it?

The oxygen–carbon dioxide cycle. *Oxygen is used by all plants and animals. They need it in their bodies for the oxidation of food material to secure energy. As a result of oxidation they give off carbon dioxide. Carbon dioxide is used by green plants in photosynthesis. In this process the plants produce far more oxygen than they need. Animals produce no oxygen. They do, however, breathe out or otherwise give off quantities of carbon dioxide. Thus the green plants by the process of photosynthesis supply oxygen which animals must have. The animals supply carbon dioxide which green plants must have for carrying on photosynthesis. This exchange of oxygen and carbon dioxide is called the oxygen–carbon dioxide cycle.

Summary. **Photosynthesis* is the process by which the chlorophyll in green plants changes water and carbon dioxide into carbohydrates by means of the sun's energy. Photosynthesis takes place almost wholly in the leaves. Water from the soil travels from the roots through the vascular bundles to the leaf. Carbon dioxide enters the leaf through the stomata. Water and carbon dioxide are combined by chlorophyll to form the carbohydrates grape sugar and starch. Oxygen is a by-product of this chemical action.

Self-test. 1. Name one or more functions of each of these leaf structures: (1) stomata; (2) guard cell; (3) chlorophyll; (4) veins.

2. The process by which green plants manufacture food with the aid of the sun's energy is known as (1) protoplasm; (2) phototropism; (3) poliomyelitis; (4) photostatic; (5) photoelectric; (6) proton; (7) phosphate.

3. Select from the following list the substances that enter or leave green plants through (*a*) the roots, (*b*) the leaves: (1) carbon dioxide; (2) water; (3) water vapor; (4) oxygen.

4. Carbohydrates are made of the elements --?--, --?--, and --?--.

5. Only green plants can make *fats* but animals can also make *proteins* and *carbohydrates.*

6. Food is circulated throughout a plant in the form of *starch.*

7. Food is usually stored in plants in the form of *starch.*

WHAT ARE THE NATURE AND THE IMPORTANCE OF TRANSPIRATION?

Transpiration. As has been stated, water is constantly passing by osmosis from the soil into the roots of plants. An experiment will show what becomes of this water.

Experiment 13.[1] Does water pass up through the stem and out of the leaves of a green plant? Select a leafy plant or a branch, the stem of which is only slightly larger than the holes in a two-hole rubber stopper. Insert the stem in one of the holes of the stopper. Fit into the other hole of the stopper a glass tube of the form shown in the figure. Fill a bottle entirely full of water and insert the stopper tightly enough for some of the water to be forced almost but not quite to the end of the longer arm of the tube. There should be a small air space between the water in the tube and the level of the water in the flask, as shown in the figure. Place a cellophane bag over the plant, and tie it closely around the stem.

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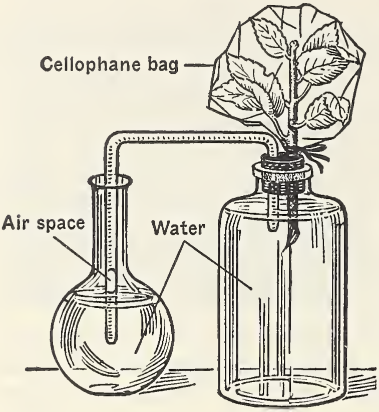
[1] Adapted from an experiment suggested by Professor A. R. Sweetser.



Exercise on Scientific Method (Using Controls): The plant, when stripped of its leaves, served as a control. Explain. The experimental factor was the presence of leaves. Explain

Observe the air space in the tube at the end of an hour and again the next day. What happens? Observe the inside of the cellophane bag. Summarize your observations and conclusions in a few sentences or by means of diagrams. Now lift the tube from the flask so as to admit a little air into the long end of the tube. Then strip all the leaves from the plant stem. Replace the tube in the water in the flask. The apparatus will now look as in the figure, except that the plant will have no leaves. Watch the air space in the tube. What happens? Summarize your observations and conclusions in a few sentences or by means of diagrams.

*Water is constantly passing from green leaves into the surrounding air. In the air spaces within the leaf there is always much water vapor, which is due to the evaporation[1] of water from the moist cell walls. As the air passes out through the stomata, much of the water vapor is carried with it out of the leaf. This particular kind of evaporation is called transpiration.[2]

All vegetation daily transpires[2] quantities of water so great that one cannot comprehend them. For example, an oak tree with about seven hundred thousand leaves transpires more than one hundred gallons of water daily during its active growing period. It is believed that water is sometimes transpired and condensed again and again before it finally flows all the way down to the sea.

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[1] *Evaporate* (ē văp′ō rāt): to change from a liquid or a solid to a vapor or to change a liquid to a vapor. *Evaporation* (ē văp ō rā′shŭn): process of evaporating.

[2] *Transpire* (trăn spīr′): to give off excess moisture in the form of vapor. *Transpiration* (trăn spī rā′shŭn): the process by which green plants give off excess water in the form of vapor through the stomata of their leaves.

Acme

The amount of water transpired by one and one-half acres of cabbages during the growing season of four months would fill a swimming pool 60 feet long and 30 feet wide to an average depth of 5⅓ feet. One cubic foot of water equals 7.47 gallons. How many gallons of water are transpired by the cabbages in four months?

Biologists are not certain about what purposes transpiration serves for the plant. Some studies show that sometimes it is more harmful to the plant than useful. It is true that soil water contains only very small quantities of the minerals that the plant requires. Therefore a considerable amount of water must be taken in to supply its needs. When the minerals have been used, the surplus water is transpired. Also, the water vapor given off probably helps to keep the plant cool, in much the same way as the evaporation of perspiration helps to cool us. Yet the plant transpires much greater quantities of water than are needed merely to cool it. In fact, water is often transpired by the leaves faster than the roots can find and absorb enough more water to replace what the plant has lost. The result is that the plant wilts. It is true also that the plant takes in far greater quantities of water than are actually used in making various kinds of foods. Therefore there is a surplus, which must be given off.

Why water rises in plants. The causes for the rise of water to the tops of the tallest plants are not yet fully understood. These causes include osmosis and transpiration, but there are other known processes which doubtless assist.

By osmosis, liquids from the soil continually enter the roots and then, by the same process, pass into the vascular bundles. This constant passage of water into roots creates a pressure (root pressure).[1] This pressure tends to force the water upward. Recent experiments show that this pressure is probably the chief influence causing water to rise in plants. Small roots of several kinds of plants, when not connected with the rest of the plant, recently have been found to exert pressure sufficient to account for a rise of water as high as four hundred feet.

As a result of transpiration the evaporation of moisture from the leaves decreases the amount of water in the leaf cells. Consequently the greater osmotic pressure in the living cells of the stem forces water into the leaves. Then, as the amount of water in the stem becomes less, the osmotic pressure in the roots forces water into the stem.

Other processes (imbibition and capillarity) probably account for much of the rise of water through the older, or dead, cells of a plant. By these processes water enters the dead cells and the microscopic pores and spaces in cell walls in much the same way that water rises in the pores of a blotter and in very small tubes.

All the influences just described, however, are not enough when combined to explain fully the rise of water to the tops of plants. Scientists have further problems to solve in explaining this process.

The leaf factory closes. In the Temperate Zones the period of favorable weather for photosynthesis is usually three or four months. It may be shorter or longer in different years. In the cases of many small plants all the activity of the chlorophyll for the entire year is completed in a few weeks. Spring beauty, crocus, dogtooth violet, and many other small plants produce their flowers and make their food early in the year. Then the leaves die, and the part of the plant under the ground lies dormant until the next growing season.

Many plants shed their leaves at the end of the growing season. Thus the evaporating, or transpiring, surface of the plants is greatly reduced. Deciduous trees and shrubs prepare to drop their leaves by forming a layer of hard-walled cork cells at the base of each leaf. This layer serves to cut off the leaf from the twig or the branch on which it grows. Before this layer of cells is formed, most of the food and living substance of the leaf is withdrawn into the other parts of the plant.

When the chlorophyll is less active and while preparation is being made for shedding the leaves, striking colors often appear in the leaves. These

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[1] Terms in parentheses in the text or labels in parentheses in the illustrations are not intended as essential vocabulary (see the Preface, p. v).

Hepaticas. When do plants such as these, which grow in the shady woods, do most of their food-making?

colors are not caused by frost, as is sometimes said. They result from the chemical and physical changes related to shedding the leaves when their work is done.

Evergreen trees are in less danger from excessive transpiration than deciduous trees because (1) their leaves are smaller and narrower and (2) their leaves have fewer stomata. As autumn advances, evergreen trees are protected against harmful evaporation by a thickening of the leaf epidermis and by a closing of the stomata with a wax-like secretion.[1] The next year the evergreens will not have to produce all their leaves anew. However, they will have smaller chlorophyll surfaces for their season's work than the deciduous plants, which produce a wholly new set of broad and actively working leaves.

Summary of leaf functions. *The discussion of leaves has thus far dealt chiefly with photosynthesis and the closely related process of transpiration. These processes are, however, only two of the functions of leaves. Another important function, in addition to (1) food-making by photosynthesis and (2) transpiration, is (3) respiration, a process which will be discussed later.

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[1] *Secrete* (sē krēt′): to form a new substance from body fluids, such as sap or blood. *Secretion* (sē krē′shŭn): a special substance secreted usually by a gland.

Certain leaves, moreover, may be adapted to performing special functions, such as those of (4) protection (spines, thorns, and bud scales); (5) food storage; (6) water storage; (7) attaching the plant (by tendrils) to a support; (8) even in some cases capturing insects, which serve as an addition to the food supply obtained by photosynthesis. These various functions will be discussed in later parts of this book.

Self-test. **1.** The evaporation of water from green leaves is called --?--.

2. Transpiration results in differences of *pressure* between the tops and the roots of trees.

3. Evergreen leaves in general transpire less moisture than the leaves of deciduous trees because (1) --?-- and (2) --?--.

4. Trees lose *more* water by transpiration after they have dropped their leaves than before.

Self-test on Important Biological Terms

carbohydrate
chloroplast
photosynthesis
secretion
stomata
transpiration
vascular
vascular system

Self-test on Biological Principles. Can you explain how the process of photosynthesis illustrates the principle "Division of labor takes place in complex organisms"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. **1.** Discuss photosynthesis (see "How to Study," p. x).

2. Explain how transpiration and precipitation, or rainfall, compose a cycle.

3. Why do evergreen trees need a less abundant supply of leaves than deciduous trees during the active growing season?

4. If a tree or a shrub is pruned too closely, it will die. Explain.

5. The upper epidermis of leaves usually is thicker than the lower epidermis What advantage does the plant derive from these adaptations?

6. When a shrub or tree is to be transplanted, the leaves are trimmed off rather closely. Why?

7. If, early in the spring, there is an unusually warm period followed by colder weather, deciduous trees or shrubs may be killed. Explain.

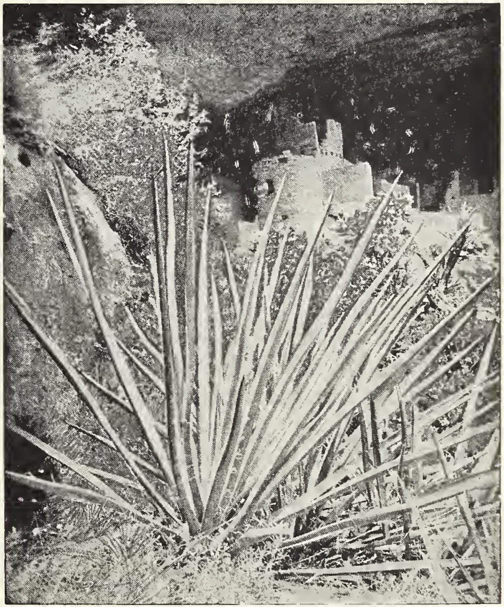
8. Does sprinkling leaves with water help the plant to secure the moisture it needs? Explain.

9. In what respects should you expect a leaf which has grown vertically, as that of iris or tulip, to differ from one which has grown in a horizontal position?

10. On which surface of a water-lily leaf should you expect to find the greater number of stomata? Why?

Exercise on Scientific Method (Making Hypotheses). Deciduous trees are much more frequently blown down by strong winds than are evergreen trees. How many reasons can you suggest which might account for this fact?

Project 3. To make a study of the stomata and their arrangement and distribution on various kinds of leaves. Secure a number of different types of leaves, from deciduous shrubs, weeds, water plants, and the like. Prepare microscope slides of the upper and lower epidermis of each leaf. Make sufficiently numerous and accurate sketches to indicate clearly any differences which you observe in the stomata themselves or in their distribution on the various leaves.



United States Department of the Interior

Spanish bayonet and old cliff dwellings, Mesa Verde National Park. Does photosynthesis go on in such a plant as this? Explain. Does it also go on in a cactus? Explain

CHAPTER VII

Different Structures for Different Uses

Questions This Chapter Answers. 1. What is the general structure of stems? · 2. What are the important differences between the stems of monocots and dicots? · 3. What are the structures and functions of the vascular bundles? · 4. How do stems increase in length and thickness? · 5. What are the most important functions of stems? · 6. In what ways are plant stems used by men? · 7. What are the important structures and functions of roots? · 8. In what ways are leaves, stems, roots, seeds, and fruits used as storehouses of energy? · 9. What purposes are served by the food which plants store?

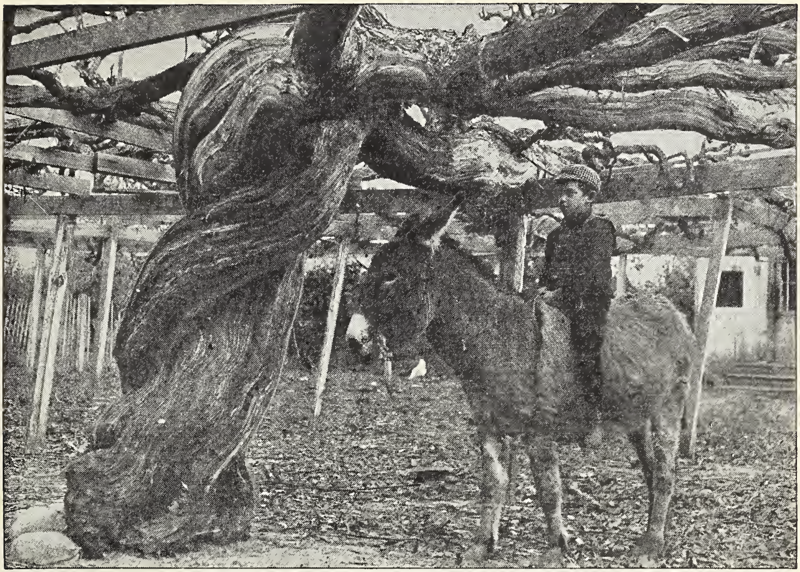
WHAT ARE SOME OF THE STRUCTURES AND FUNCTIONS OF PLANT STEMS?

Different kinds of stems. A California sequoia tree may have a stem more than three hundred feet long. A dandelion, in contrast, has a stem so short that it merely connects the leaves and roots. Most stems, as those of bushes, trees, and many smaller plants, are erect. Some, however, as those of a pumpkin plant or a watermelon plant, lie directly on the ground. The stem of a sequoia tree may be strong enough to support many tons of weight. In contrast, the stem of a climbing plant, like the wild grape, may be more than a hundred feet long, but it depends on trees or other structures for support.

Some plants have underground stems; that is, their stems are partly or entirely underground. Such stems are readily distinguished from roots because they have the characteristic structures of stems. The parts of such plants that we see above ground are either branches or the petioles of leaves.

There are several types of underground stems. They differ from one another in form, structure, and position. Many plants, such as Solomon's-seal, wild ginger, iris, quack grass, Canada thistle, and some ferns, have the type of underground stem (rhizome) from which either branches or leaves with strong petioles grow into the air from different points. Such plants as the onion, the tulip, and the lily have underground stems called bulbs. A bulb is composed chiefly of leaves attached to a small stem. Plants such as the gladiolus, Indian turnip, jack-in-the-pulpit, and crocus have rounded underground stems (corms). The leaves are not distinct but are scale-like structures on the surface of these stems. The white potato has still another type of rounded underground stem, called a tuber. This type has buds (eyes) along the sides.

*It is obvious that stems vary in many ways. Yet all stems have two chief functions: (1) to support the leaves in such a way that they can receive the sun's energy and (2) to transport liquids from one part of a plant to another.



This grape-vine, the largest in the world, was planted at Carpinteria, California, in 1842. In 1900 it bore more than ten tons of Mission grapes, and over a period of many years it produced an average of more than eight tons. The vine died in 1920. Is such a climbing plant as this a dependent plant? Explain

Stem structures of monocotyledons and dicotyledons. Flowering plants are grouped into two great classes, monocotyledons[1] and dicotyledons.[1] Common monocots are corn, lilies, and the grasses. The dicots include most trees and such common plants as the peanut, the bean, the pea, and the sunflower.

In the stems of both monocots and dicots are found (1) the outer protective region, (2) the vascular system, and (3) the pith. The outer protective layers of both monocot and dicot stems consist of the epidermis and the cortex. In young stems these layers may contain chlorophyll, and therefore may carry on photosynthesis.

The cortex of a monocot stem is composed of thick-walled cells. The chief functions of this region are (1) to provide strength and support for the plant and (2) to protect it.

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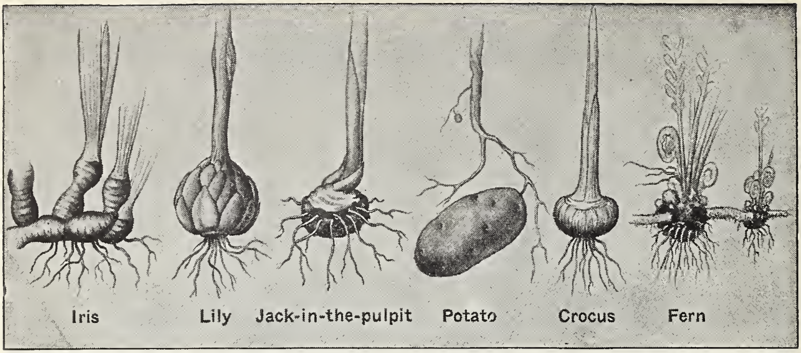
[1] The terms *monocotyledon* (mŏn ō kŏt ĭ lē′dŭn), *monocot,* and *monocotyl* have identical meanings. Likewise the terms *dicotyledon* (dī kŏt ĭ lē′dŭn), *dicot,* and *dicotyl* have identical meanings. See the Glossary for definitions of monocot and dicot.



Underground stems. What plant structures which grow above ground and in which food is stored can you name? How can one distinguish underground stems from roots?

As a young dicot tree develops, certain regions of the bark are formed under the epidermis by the growing layers of the cortex. Frequently, as the plant matures, the epidermis is lost. The outer bark of mature dicot stems is composed chiefly of dead cells. The principal functions of the epidermis and cortex of dicot stems are (1) to protect the plant from too great loss of water and (2) to protect it from the attacks of insects and other enemies.

Young stems differ somewhat from old stems of the same kind of plant. Yet all stems have certain structures in common.

Experiment 14. What is the general structure of a young dicot stem? Secure several young branches of maple, willow, apple, or other trees. Cut sharply across one end of each so that you have a smooth surface to study. In each stem locate the bark, with its epidermis (outer layer) and cortex. What is the color of each of these regions? Is the color the same in all the stems? Find the woody[1] vascular region in each stem. You will recognize it as a group of cells arranged in a rough circle. Examine the pith in the center of each stem. Is it harder or softer than the other tissues of the stem? Are your observations the same for all the stems?

Evaluate procedures (see "Elements of Scientific Method," stated on page 625) by answering the following question: Was it better in this experiment to use stems from several different kinds of trees than it would have been to use only one stem? Explain.

The vascular system. Vascular bundles can best be seen in a monocot stalk, such as that of corn or tulip. If such a stalk is broken across, and if

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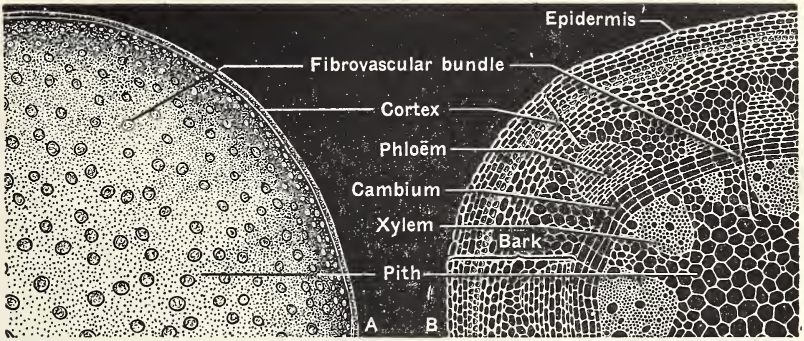
[1] *Woody* (wŏŏd'ĭ): composed of tissues of wood.



Compare the monocot stem (A) with the dicot stem (B). (See "How to Study," p. x)

one part is carefully pulled away from the other, thread-like fibers are seen scattered through the pith at the broken surface. These fibers are vascular bundles, or fibrovascular bundles. Vascular bundles are essential structures in all stems. One important function of the vascular bundles is shown by Experiment 15. Other functions will be described later.

Experiment 15. Through what parts of stems do liquids move upward? Cut several living stems of monocots, such as corn, lily, or narcissus, and also young twigs of dicots, such as willow, maple, or apple. As soon as they are cut, place the cut ends in red ink or in a solution of eosin. Within an hour or so, if possible, but, if not, on the following day, remove the pieces of stems and cut off the parts that were submerged in the colored liquid. Examine the cut ends that were above the liquid to see if there are colored regions showing where the liquid passed upward in the stems. Then cut the stems lengthwise, that is, from end to end, to see how far the liquid passed upward. Summarize your observations in brief statements or by diagrams.

In this experiment a check experiment is introduced. Why is it better to use several stems rather than only one?

The vascular bundles of monocots and dicots are characteristically arranged, as will be seen in Experiments 16 and 17.

Experiment 16. What is the arrangement of the vascular bundles in the stem of a monocot and of a dicot? Cut very thin cross sections of one of the twigs and of the cornstalk used in Experiment 15. Be sure that each section shows clearly the structures through which the liquids passed upward in the stem. Hold each section to the light and locate the vascular bundles. Where are they with reference to the pith?

Experiment 17. What are the arrangements of different types of cells in monocot and dicot stems? Mount a very thin section from both stems on a microscope slide and examine each with the low-power objective of the compound microscope until you locate one of the vascular bundles in each. Make statements or diagrams indicating the characteristics of the cells of the monocot and the dicot through which the red liquid passed upward.

If you have specially prepared slides of typical monocot and dicot stems, study them carefully after you have examined the slides you have made. Note the structure of the cells surrounding the vascular bundles and of the cells in the region at the outer edge of the stem. Compare what you observe with the figure on page 97. Describe or indicate clearly by diagrams the differences you note between these cells and those of the vascular bundles. Note especially any differences in the vascular bundles of the monocot and the dicot. Your diagram or description of the dicot stem should clearly show the nature and the location of pith, vascular bundles, bark, and pith rays (or medullary rays). Your diagram or description of the monocot should show the rind (or cortex), the pith, and the vascular bundles. Compare the vascular bundles you are observing with the cross section of a vascular bundle in a leaf shown in the figure on page 80.

*In a monocot stem, as a cornstalk, the vascular bundles are separate and are scattered throughout the pith. In a young dicot stem, such as a bean or pea seedling, the bundles are likewise separate. They are not scattered, however, but are arranged in the form of an incomplete cylinder inside the cortex. As the dicot stem grows, the bundles are crowded closer together, so that in mature dicot stems they form a solid cylinder of tissue surrounding the pith.

The pith of both monocot and dicot stems is composed of dead cells. These are light and may hold moist air, stored food, or sometimes solid waste materials of the plant.

Vascular bundles. The vascular bundles in the stem are continuous with the vascular bundles (that is, the veins) of the leaves, and extend downward into the roots. Thus there is a continuous line of vascular bundles from the roots through the stem and the branches into the leaves.

*A vascular bundle consists of several kinds of cells. In the dicot bundle three kinds are especially important, and these three compose almost the whole bundle, as will be seen in figure *B* on page 97. These are (1) the heavy-walled wood cells, called xylem, found on the side of the bundle nearest the center of the stem; (2) the thin-walled outer cells, called phloem; and (3) the small thin-walled cells which form a layer, called the cambium, between the xylem and the phloem. Water passes upward in the stem through the cells of the xylem. Food materials pass from the leaves downward in the stem through the cells of the phloem. Almost all growth of the plant in thickness is accomplished by the cambium.

Hawaii Tourist Bureau

Coconut palms on a Hawaiian beach. The palm is one of the largest monocots. **Special Report:** Uses of the palm tree

In dicots the woody cells of the xylem provide the chief support of the stem. In monocots, as has been stated, the cortex, and not the xylem of the vascular bundles, supports the stem.

The pith in the center of a dicot stem does not continue to grow. It dies and is soon crowded into a very small space. In older stems, like tree trunks, it may have disappeared entirely. The only pith tissue which remains is found in the pith rays. These extend outward from the center, separating the vascular bundles. They conduct liquids horizontally across the stem.

Self-test. 1. *All* plant structures that grow under the ground are roots.

2. Name the three important regions which all stems have and state the functions of each.

3. The different structures of the young plant stem, named in their order from the outside of the stem to the center, in general are *pith, epidermis, cortex, vascular bundles.*

4. The stems of *old* plants to some extent share with the leaves the process of photosynthesis.

5. The *cambium* layer serves as the means of transporting liquids upward through the *stem*.

6. The *xylem* tissues serve as the means of transporting *liquids* downward through the stem.

7. The growing tissues of the plant are located in the *phloem*.

8. In the *dicot* stem the vascular bundles are arranged in the form of a cylinder, near the *center*.

9. In the *monocot* stem the vascular bundles are scattered throughout the *cambium* of the stem.

10. The pith rays of the dicot carry water *vertically* through the stem.

HOW DO STEMS GROW?

How stems increase in length. Plant stems grow both in length and in thickness. Growth in length results from the development of buds. Growth in thickness takes place in the cambium region of the vascular bundles.

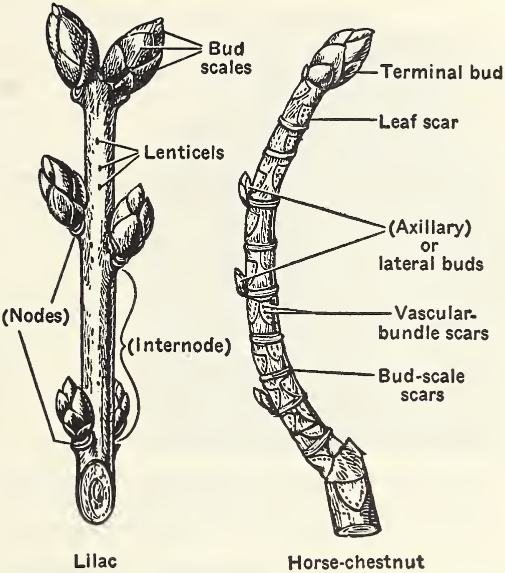
Experiment 18. What is the structure of a bud? During springtime, abundant illustrations may be collected out of doors. Even during the winter months the buds of many kinds of trees and shrubs will develop if twigs are placed in jars of water in the classroom. Secure twigs, some having dormant buds and others having buds that are starting to open. By the use of a hand lens, find what covers the bud and what parts can be found inside this covering. By comparison with a growing bud of which the growing part has become an inch or more long, determine what parts are present in both dormant and developing buds. What takes place in the process of growth from a bud? If it is available, study an unopened flower bud of a lily, an amaryllis, a geranium, or any other flower. Compare the parts of the bud with the parts of an opened flower. (See "How to Study," p. x.) Are all the parts of a flower present in the unopened bud?

While usually we do not notice tree buds until they begin to unfold in the spring, they have been on the tree all winter. Buds are formed in the late summer and fall, and remain dormant until the next growing season.

*Buds are important structures in both monocot and dicot stems. A bud consists of a very short piece of modified stem to which are attached small tightly folded leaves and sometimes flower parts. The inside of the bud is protected by several layers of modified leaves, called bud scales.

There are three kinds of buds—leaf buds, flower buds, and mixed buds. (1) A leaf bud contains only leaves and the short stem to which they are attached. When a leaf bud begins to grow, its stem becomes longer, causing the leaves to become separated. (2) A flower bud is very similar to a leaf bud in general structure. It differs from a leaf bud, however, in having parts of the bud modified to produce seeds. Separate flower and leaf buds are found on such plants as cherry, plum, apricot, and walnut trees, as well as on many common garden plants. (3) A mixed bud contains both leaves and flower parts. Mixed buds are found on such plants as oak, apple, pear, and grape.

Buds may be formed both at the tip of a stem or a branch and along the side of a stem or branch. In a monocot, which consists of a single stalk, both the leaves and the stem develop from the growing bud at the tip of the stem. In a dicot, growth of the bud at the tip of a stem increases the length of the stem, while growth of buds along the side of the stem causes branching.



Locations of buds on twigs. Can you tell from a study of the scars whether these twigs are more than one year old? Explain

How stems increase in thickness. Almost all growth of a plant in thickness results from the increase in the number of cells in the cambium. Each cambium cell divides, forming two new cells.

In monocots the vascular bundles of very young stems contain cambium. This develops into xylem cells on the inside and phloem cells on the outside, but does not continue to form new cambium tissue. The result is that mature monocot stems can grow thicker only by an increase in the number of vascular bundles and by a slight increase in the size of the xylem and phloem cells. Most monocot stems that are old remain of about the same thickness because the number of their vascular bundles does not increase.

Only a very few monocot stems, such as the palms, grow tall. Their supporting tissues do not make it possible for them to carry heavy tops like those of forest trees. Most monocots must live close to the earth, since their stems do not grow strong enough to lift their leaves high into the sunlight.

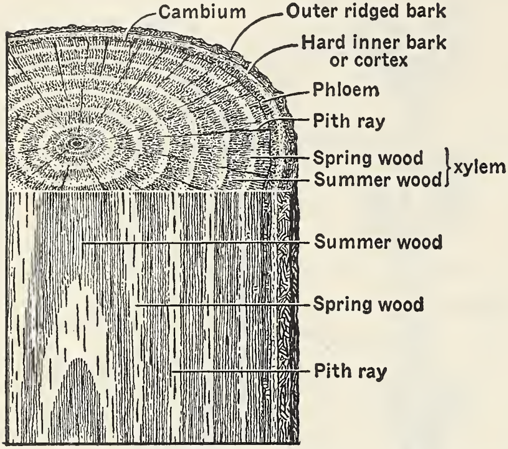


Diagram of stem showing annual rings. The color and thickness of rings vary in different stems and in different years. What are the functions of the labeled parts?

*In dicots the vascular bundles of young stems contain cambium. As long as the plant lives, this cambium forms not only new xylem and new phloem, but also new cambium between the xylem and phloem. The growing layer of cambium in every bundle is capable of adding to the thickness of the stem.

As the xylem and phloem cells are pushed farther and farther apart by the growing cambium, their cell walls become thicker. The xylem cells form a new ring of woody tissue. The phloem cells form a new layer of bark tissue. Thus the young stem develops the character of an old stem.

Annual rings. The layers of cells produced by the cambium in one growing season form an annual ring thus: In the early part of the growing season the cambium produces large cells. These large cells serve to carry rapidly the water and food needed by the developing leaves. During the hot and usually drier summer weather, the xylem cells which develop are smaller. The summer wood, therefore, appears darker than the spring wood. This difference in appearance makes it easy to determine the approximate age of the tree by counting the number of yearly growth rings.

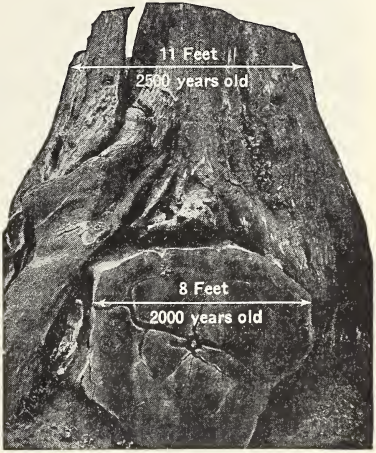
Such annual growth rings of woody tissue are found, of course, only in dicots and in evergreen trees,[1] such as spruce, hemlock, fir, and redwood. When a prolonged drought has occurred and is followed by favorable growing weather, trees may have a second growth period. In such a rare case it is possible for two rings of wood to be formed in a single year.

There are, of course, new annual rings formed in the bark too, as new layers of phloem cells are produced. But these rings are smaller than those

[1] The structure of an evergreen stem (gymnosperm) is somewhat different from that of a dicot stem, and is more complex.

in the wood and therefore are not easy to count. Besides, as the bark grows older, the outside layers of old phloem cells may peel off or be torn away.

The attractive "grain" which we observe in such wood as oak is due largely to the alternate layers of spring wood and summer wood in an annual ring. Other conspicuous markings on a piece of lumber are caused by the pith rays (medullary rays). Differences in the pattern of the grain are brought out by the angle at which the lumber is sawed.



California redwood stump and log. The stem of the older of these two California redwoods fell, and at some later time the other tree began to grow upon the fallen tree. The ages of the two trees together totaled more than forty-five hundred years. How were the ages of these trees determined?

Experiment 19. How old is a stem? Cut a young stem of apple, maple, willow, or other dicot. Count the growth rings from the center to the outside. If each ring represents a year, how old is the stem? Do the old bud scars on a twig provide another way of finding how old the twig is? Answer in complete sentences.

***Summary of stem functions.** The preceding discussions have emphasized chiefly two important functions which the stem of every plant must serve. These functions are (1) to uphold and present the leaves to the sunlight so that food manufacture by the process of photosynthesis may go on; (2) to provide for transportation of water and minerals to the leaves and of manufactured food materials from the leaves to all parts of the plant. In the larger plants the stems (3) must also support themselves and the weight of their branches, leaves, and fruit even when there is a heavy wind or a heavy fall of snow or sleet. Furthermore, in some plants the stems serve (4) as a place of storage for surplus food and (5) as a place of storage for certain waste materials which the plant cannot get rid of otherwise. In some plants the stems (6) contain chlorophyll and therefore take some part in the work of photosynthesis. Also, some stems (7) serve as a means of propagation, that is, of reproduction.

Economic[1] importance of stems. Man uses plant stems for many purposes. The stems of many trees furnish lumber for building and pulp for paper.

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[1] *Economic* (ē kō nŏm′ĭk): related to money profits or losses.

Stems are used for fuel, especially in localities where coal, oil, or gas is not readily available. The stems, or the leaf stalks, of celery, asparagus, rhubarb, and many other plants are used as food. From the stems of sugar cane much of our sugar is obtained. Linen is made from the fibers in the stems of flax plants. Rope is made from similar fibers in hemp, banana, and some other plants. Rubber, turpentine, and resin, as well as camphor, spices, and many important drugs, medicines, and flavors, are prepared from plant stems.

Self-test. **1.** Name a distinguishing characteristic of each type of bud.

2. Stems and branches grow longer by means of *buds* which develop on their *sides.*

3. The tip of a growing point of a stem is protected by modified *cortex.*

4. The branches of dicots develop from *flowers* on the branches.

5. *Monocotyledons* develop cambium in their *vascular* bundles as long as they live.

6. Dicots *always* have one growth ring each year.

7. Name seven functions of stems.

WHAT ARE SOME OF THE STRUCTURES AND FUNCTIONS OF ROOTS?

Various types of roots. Many plants have roots which branch from the base of the stem, and divide again and again until the root system resembles the branching top of the plant. Usually the roots of a plant extend at least as far outward as its branches. This habit of growth serves both to anchor the plant firmly and to permit the roots to gather as much moisture as possible.

Experiment 20. Are there definite types of root systems in different plants? Carefully remove from the ground a number of plants, such as weeds of various sorts, grasses, and vegetables, with considerable amounts of soil attached. Remove the soil from around the roots by careful washing. Compare the root systems. Do any have a single main root with numerous small roots? Do any have several main roots of about equal size? Do any have no main roots but instead a large number of roots of about equal size? Are there other distinct types? Summarize the results of your observations with statements or diagrams.

Evaluate your data (see "Elements of Scientific Method," presented on page 625) by answering the following question: Can you be sure that from your observations you have discovered *all* the different types of root systems? Explain.

Root structures. Many plants, chiefly dicots, have one central root. This root is large, strong, and deeply placed. It branches to form the smaller roots. This main root, which descends from the base of the stem, is called a *taproot.*

With so many roots exposed, what holds the trees upright?

Such a taproot is found in the hickory, walnut, pecan, some oaks, the carrot, beet, parsnip, and turnip. In the last four plants the taproot is also a structure for storing surplus food.

In other plants, chiefly the monocots, root systems (fibrous roots) are finely divided. Such plants have no taproot or main large roots. Some plants, such as woodbines and ivies, in addition to their roots, develop along their stems root-like structures (holdfasts). With these they cling to other plants or to rocks or walls for support. In some plants which are parasites, as the mistletoe, the roots actually penetrate the host plant (see the figure on page 53). These roots spread in the phloem of the host branches and take food from the host plant.

Experiment 21. How are roots adapted for securing water and dissolved minerals from the soil? Plant a few beans, peas, or corn grains in moist sawdust or sphagnum moss. After they have begun to sprout, remove the seedlings and examine them carefully. Can you find the primary root, that is, the first root formed? the secondary roots? the root hairs? Describe in a sentence or by means of a diagram any structures that you observe which might be of use in securing water and minerals.

Experiment 22. What is the structure of a root? Soak some pea seeds and place them between moist paper towels or sprout a wandering-Jew plant (*Tradescantia*) in water. Cut off a very small root and make a slide of it, using a little water. Examine it with both the low power and the high power of the microscope. Do you find one or more vascular bundles? Can you determine whether or not the root as a whole is made up of cells and whether or not the bundles are composed of cells? Can you find any root hairs? Describe your observations in a few sentences or by means of diagrams.

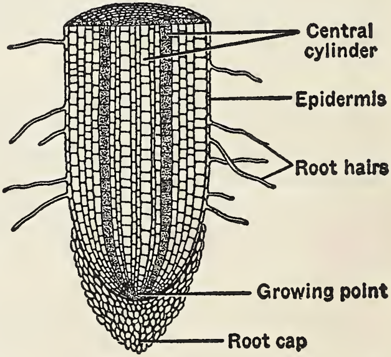
Cut from a young root of wandering Jew or other plant a thin "up-and-down" (longitudinal) section. Mount it on a microscope slide and examine it as directed above. What differences do you observe in the cells in different parts of the root? Compare your slide with the figure at the bottom of this page and locate the structures named.

Place the root of a seedling in eosin or red ink. After a day cut cross sections and examine them to see whether you can find the tissues through which the liquid rose. Describe your observations in a few sentences or by means of diagrams.

Seedlings of a monocot (corn) and a dicot (bean). Compare these two seedlings (see "How to Study," p. x)

*In general, the structure of a root is very similar to that of a stem, as will be seen in the figures on pp. 106–107. The chief parts of a root are (1) the epidermis, which is a thin layer of cells on the outside; (2) the cortex, which consists of a number of layers of cells; and (3) the central cylinder, which contains the vascular bundles. The epidermis absorbs moisture from the soil. The moisture passes by osmosis from the cells of the epidermis through the cells of the cortex and then into the vascular bundles. As in a stem, the vascular bundles of the root contain xylem tissue, which carries water and sap upward, and phloem tissue, which carries food downward. The cortex serves both to protect the inner structures of the root and to store food and sometimes water. The growing part of the root is almost at the end.

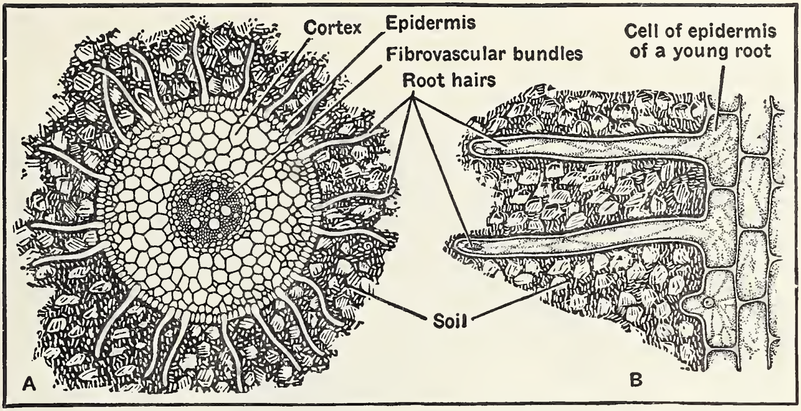
Root hairs. During the growing seasons the cells of the epidermis in the smallest roots (rootlets) produce hair-like growths, called root hairs.



Longitudinal, or lengthwise, section of a root. State the functions of the labeled parts

Experiment 23. What is the structure of a root hair? Mount on a slide a piece of a root which shows root hairs. Examine it under both low power and high power. Make a diagram of its structure.

*A root hair is merely a part of a cell of the epidermis. Its protoplasm is continuous with that of the cell from which it grows. The root hairs come



Can you describe the functions of the labeled structures in these diagrams, (A) the cross section and (B) the lengthwise (end-to-end) section of a young root?

into close contact with particles of soil and with soil moisture. Therefore, since they have thin walls, they are able to absorb water containing dissolved minerals from the soil. The root hairs serve to increase many times the absorbing surface of a root. If some root hairs are injured, or when root hairs become old, others may be produced to take their places.

Root hairs bear an important relation to the loss of leaves by deciduous trees in the fall. As the soil becomes colder, root hairs are developed less and less abundantly. As a result, the water supply of the plant is finally almost stopped. The plant then begins to shed its leaves because not enough water reaches the leaves to enable them to carry on photosynthesis. By dropping its leaves the plant reduces the amount of transpiration, and thus adjusts itself in part to the reduced water supply from its roots.

Root growth without soil. We are likely to think that plants must grow in soil in order that their roots may secure the needed minerals. It has been known for more than fifty years, however, that plants can be made to grow and mature entirely without soil if their roots are kept in nutrient[1] solutions. The first attempts to grow vegetables and flowers for market by this means were made a little more than ten years ago. Since then fruits, vegetables, and flowers of many kinds and of excellent quality have been grown without soil. By this method it is possible to grow spinach, tomatoes, melons, beans, and many other food plants in homes, on roofs, and in places where there is no soil suitable for agriculture. Though this method of growing crops has been

[1] *Nutrient* (nū'trĭ ĕnt): furnishing nourishment.

Frank J. Taylor and *Saturday Evening Post*

Wake Island, captured by Japan in 1942 and surrendered by her in 1945, is a coral reef where only desert plants will grow. Here enough fruits and vegetables to supply the inhabitants and the airplane passengers are raised in soilless gardens. Why can such crops be grown in tanks but not in the island soil?

proved to be practical, it is not expected to take the place of ordinary methods of growing food plants in the soil.

Summary of the functions of roots. *The most important functions of roots are (1) to support the plant; (2) to absorb soil water; (3) to conduct liquids. In certain plants, such as the turnip, beet, and other root vegetables, the roots serve (4) as the chief storehouse of the plant's surplus food materials. In still other plants—for example, the sweet potato—the roots may serve (5) for propagation. Some of these functions will be discussed later.

Economic uses of roots. Man cultivates many garden plants, such as beets, carrots, parsnips, and turnips, for the sake of the food which the plants have stored in their roots. He uses for medicine the roots of a few other plants, such as ginseng, aconite, and May apple.

The roots of some trees furnish lumber needed for certain articles, such as fine furniture and frames for certain types of wooden boats.

The roots of trees and grasses are of great economic importance in preventing the erosion of soil. In the Bad Lands of South Dakota, in increasing areas in other parts of our country, and in great areas of China, the land is worthless because the fertile top-soil was washed or blown away after the plants on it had been destroyed.

Self-test. 1. A structure which the root has and which the stem does not have is *pith.*

2. Moisture is chiefly absorbed through the --?-- of the root.

3. Soil water and food materials are transported in the root through the --?--.

4. The *dicot* plant develops *more* root hairs in the fall than in the spring.

5. One would need to dig *more* deeply to remove a monocot than a dicot of the same height.

HOW DO VARIOUS PLANTS SOLVE THE PROBLEM OF FOOD STORAGE?

Food storage by plants. If the food made by a plant served no purpose except to enable that plant to carry on its life activities, there would be no need for it to manufacture surplus food and to store it. But every plant reproduces. Therefore it produces and stores enough food to supply, not only its own needs, but also those of its offspring, until the young plants have grown enough green leaves to make their own food. Man and other organisms eat various parts of plants for the food stored in them. It should be remembered, however, that no plant ever makes food for the use of man or of any other organism except itself.

Plant storehouses. Various plants store surplus food in leaves, roots, stems, seeds, or fruits. Some starch and sugar are usually present in green leaves, as immediate products of photosynthesis. Relatively few plants, however, store surplus food in leaves. These usually do not store it in green leaves above the ground, but in closely folded clusters of thick leaves underground. The onion and other members of the lily family have such leaf clusters (bulbs).

The sugar in the sap of sugar cane is transported to all parts of the plant as food. Any surplus is stored in the stem. The sweet sap of the sugar maple is food which was stored during the preceding year, and which has been changed into sugar. This sugar is distributed to all parts of the tree and serves in starting the season's growth.

Many plants store surplus food in underground stems. Such plants include the potato, iris, and quack grass. Many other plants store food in their roots.

Such plants include the beet, the turnip, the sweet potato, the carrot, and the parsnip. These plants (biennial plants) bear flowers only every other year. They store enough food in their roots the first year to supply their needs during the second. Thus, if beet seeds are planted, they grow and develop large roots the first year. But the plants do not form seeds that year. If, however, the roots are left in the ground, the stored food they contain enables them to develop new plants early the second year. These plants produce seeds.

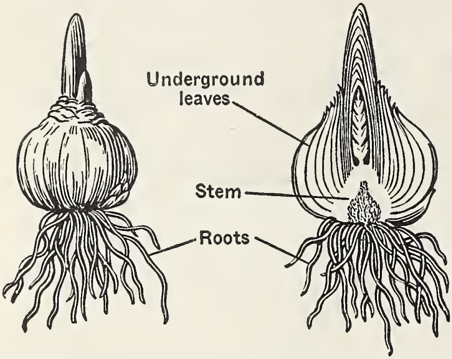


Diagram of an onion bulb. How may one distinguish the underground leaves of this plant from the stem?

Certain plants that grow in desert regions store water as well as food. One such plant of the southwestern United States, called the manroot, or wild potato, has storage roots which are sometimes several feet long and a foot thick and which may weigh as much as a man. Travelers sometimes dig up this root to secure the water stored within it. The barrel cactus stores considerable water in the tissues of its stem.

Flowering plants store food in their seeds. The amount of food stored in a seed may be very small, as in orchid or mustard seeds, or it may be very large, as in seeds of the bean, corn, wheat, or walnut. Additional foods, chiefly sugar and starch, are stored around the seeds or stones in such fruits as apples, pears, plums, peaches, and grapes. In such fruits these foods outside the seeds are lost to the plant when the fruit falls or is picked. The fruit does not serve the new plant as food, because the new plant is inside the shell and does not begin to grow until after the part of the fruit outside the seed is gone.

Self-test. 1. The function of food storage by plants is to supply food for the needs of the plant itself and for the use of *human beings.*

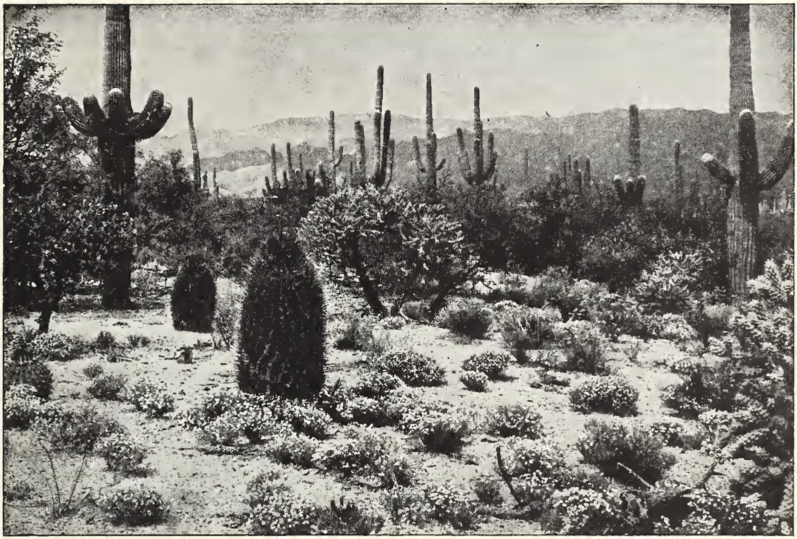
2. Plants that store food in the leaves *often* store it in thickened leaves.

3. In the common white potato surplus food is stored in the *roots.*

4. Roots of some plants contain both surplus food and surplus --?--.

5. A young peach plant consumes *little* of the fruit around the stone.

6. Some woody plants store surplus food in the *cortex.*



Shantz

Desert scene near Tucson, Arizona. The nearest large cactus is a barrel cactus. What advantage does the plant derive from being able to store water?

Self-test on Important Biological Terms

bud
cambium
cortex
dicot
epidermis
monocot
phloem
pith
root hair
xylem

Self-test on Organization of Materials Illustrating a Principle (Division of Labor). First define *division of labor,* making a complete sentence. Then make an outline similar to the following:

Division of Labor in a Green Plant

I. Roots
  A. Functions not shared with other parts
    1. To anchor the plant
    Etc.
  B. Functions shared with other parts
    1. To transport soil, water, and food materials
    Etc.
II. Stems. (Continue the outline in the same way with stems and leaves.)

Self-test on Organization of Facts. Compare the characteristics of monocots and dicots (see "How to Study," p. ix). Add to the following points, given as samples, as many other points of comparison as you can:

Monocotyledons	*compared with*	Dicotyledons
Stems		Stems
Similarities		Similarities
1. Support leaves		1. Support leaves
2. Vascular bundles have xylem and phloem		Etc.
Etc.		
Differences		Differences
1. Stem largely pith		1. Stem mostly wood
Etc.		Etc.
Leaves		Leaves
Etc.		Etc.

When you have completed this organization, write a statement consisting of a few sentences, summarizing the important similarities and differences.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why does cutting a ring completely around the stem through the bark of a dicot tree kill the tree, while a similar cut around the stem of a monocot plant does not necessarily kill it?

2. Against what kinds of enemies does thick bark protect a plant? (See page 58, Chap. IV, list of kinds of enemies.)

3. How many economic uses of stems can you list?

4. What disadvantage would plants suffer if all of them were to store surplus food in their green leaves?

5. Why is it so difficult to cut through the dry stem of a corn plant? Why is such a stem stronger than it would be if all the hard outer cortex were compressed into a solid cylinder?

6. Warm and sunshiny winter days followed by very cold weather may result in killing evergreens. Explain.

7. Aquatic plants do not usually possess root hairs. Explain.

8. Why are young vegetables sweeter than old ones?

9. Suppose a certain tree, which is fifteen feet tall, grows in height at the rate of two inches a year. When the tree is ten years old, a nail is driven into the trunk three feet from the ground. How far from the ground will the nail be when the tree is twenty years old? Explain.

Exercises on Scientific Method. 1. *Observation and Comparison.* Study the figures on pages 96 and 110 to determine the differences between types of underground stems. List differences you can determine; then check the accuracy of your observations and comparisons by consulting an advanced biology text or an encyclopedia.

2. *Making Inferences.* If a tree is girdled late in the summer, it usually will not die at once. It will even put forth leaves the following spring and live all through that growing season. But it will die before the second spring. What facts have you learned in this chapter that explain these observations?

Project 4. To make a collection showing some differences in buds and branches. In some plants, such as lilac and sumac, the terminal buds of one year do not start the growth of the next year. This produces an irregular appearance in the younger branches. In other plants, such as maple and ash, the terminal bud produces great growth in length, and the lateral buds produce branches in opposite pairs. In most plants an injury to one or several buds often results in the growth in length being taken up by other buds which under usual conditions would not have grown in such a way. Collect and mount on a large piece of cardboard several illustrations like the one given above and write a description of each one.

Project 5. To grow plants without soil. You may use any plants you wish—either flowers or vegetables that may be grown from seeds, or cuttings of geranium, begonia, fuchsia, or a similar plant. In any case, first plant the seeds or cuttings in sand until roots have formed. Meanwhile find a suitable container in which to grow the plants. It may be of wood, glass, iron, or porcelain, of any convenient size. Make a basket of coarse wire screen, four or five inches deep, which will hook over the rim of the container. Secure enough excelsior, straw, or peat moss to fill the basket.

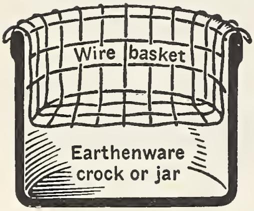
Prepare nutrient solutions of these three kinds: (1) *Stock Solution A.* Dissolve, in one-half gallon of water, one teaspoonful each of boric acid (H_3BO_3),[1] manganese sulfate ($MnSO_4$), and zinc sulfate ($ZnSO_4$). (2) *Stock Solution B.* Dissolve, in one pint of water, one-fourth teaspoonful of iron (ferric) chloride ($FeCl_3$). (3) *Culture Solution.* Dissolve separately, in one pint of water, each of these salts: one and one-fourth teaspoonfuls of monopotassium phosphate (KH_2PO_4), four teaspoonfuls of calcium nitrate ($Ca(NO_3)_2$), two and one-half teaspoonfuls of magnesium sulfate ($MgSO_4$), and one-half teaspoonful of dry ammonium sulfate ($(NH_4)_2SO_4$). Mix these four pints of solutions; then add enough water to make five gallons.

When you are ready to use the nutrient solutions, add one teaspoonful (5 cubic centimeters) of *Stock Solution A* and sixteen teaspoonfuls (80 cubic centimeters) of

---

[1] The chemical symbols of the substances are given here, together with their names, to help you in ordering them.

Stock Solution B to each five gallons of the *Culture Solution.* The stock solutions should not be added until immediately before the entire mixture is to be used. Therefore, if you are using a container which holds less than five gallons, be sure to use the correct proportions of the two stock solutions and the culture solution.



Why is a basket with a large mesh better than one with a small mesh for use in a soilless garden?

Place enough of the nutrient solution in the container in which the plants are to grow so that it will almost reach the wire basket when the latter is hooked in place. Put the plants in the basket, with the roots extending through the screen, and pack the excelsior or the moss around the stems to hold them in place. When the basket is placed in the container, the roots should touch the nutrient solution. As the roots grow longer, the level of the solution may be kept lower, so that the air space above it is increased.

About once a week lift the basket out, empty the container, and fill it with a fresh mixture of the three solutions. As the plant stems grow longer, pack more excelsior or moss around them in order to provide enough support so that the growing plants will remain upright.

Special Reports. 1. How do "air plants," such as certain tropical orchids, secure water? (Look up "epiphytes" and "orchid" in an advanced botany textbook or an encyclopedia.)

2. Why are plants such as quack grass hard to get rid of?

3. What are hydrophytes and xerophytes?

Question for Debate. *Resolved,* That dicotyledonous plants have proved of more benefit to man than monocotyledonous plants.

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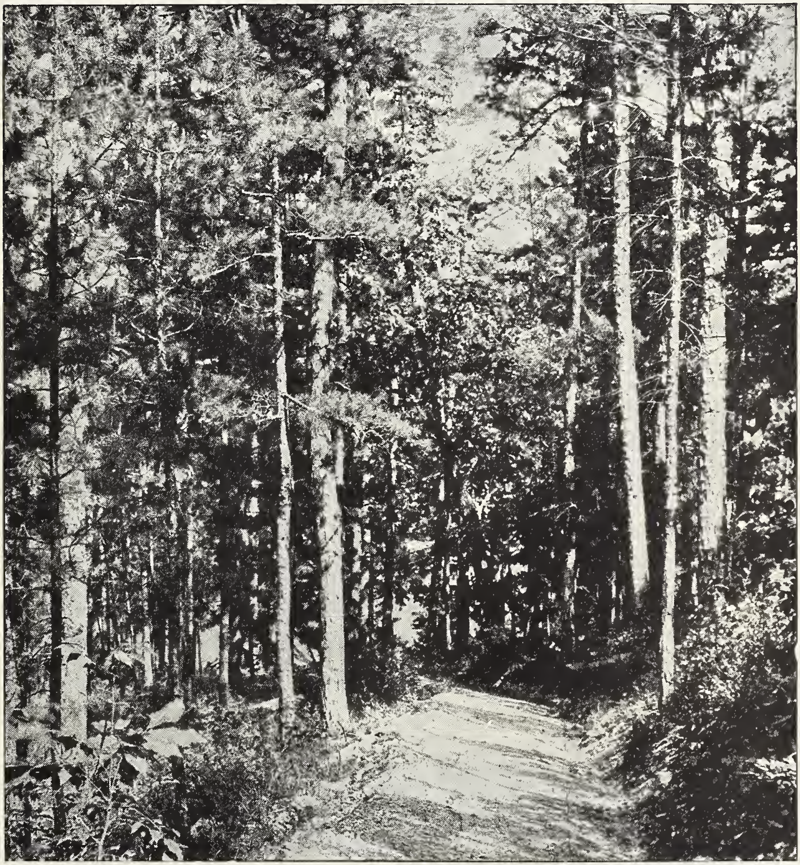


United States National Park Service

Many topics and principles discussed in the preceding chapters are illustrated in this scene from Hot Springs National Park, Arkansas. For example, can you find two kinds of enemies? evidence of the struggle for light? other illustrations of some topic or principle?

UNIT III • THE KINDS

It would be interesting indeed if we could see all the plants and animals now living on the earth. There would be more than a million different kinds. Some kinds would be found in practically every region of the earth, from the poles to the equator, from the surface of the ocean to the bottom, from the surface of the earth to the thin atmosphere several miles above the ground, and even for some distance below the surface of the earth. At one end of the scale of size would be such giants as the sequoia trees and the whales. At the other end would be living things so small that they cannot be detected by the use of the most powerful microscopes. Only a relatively few of the forms would be known by any one person.

OF LIVING THINGS

Let us suppose now that we had the gigantic task of classifying and naming all these things. Could it be done? The task would seem hopeless of accomplishment. Yet scientists have already classified and named several hundred thousand kinds of living things. It will be possible, moreover, for them in time to classify and name all the others. Furthermore, they have been able to classify and name, from an examination of fossil remains, a great number of plants and animals now extinct.

This unit tells how biologists classify plants and animals. It emphasizes chiefly, however, the structures and habits by which the various groups are fitted to succeed in the struggle for survival.

CHAPTER VIII

How Living Things Are Grouped and Named

Questions This Chapter Answers. **1.** Why is a scientific classification of plants and animals necessary? · 2. How is a scientific classification of living things built up? · 3. How are plants and animals given scientific names? · 4. How do biologists use the system of classification?

HOW ARE LIVING THINGS CLASSIFIED?

Naming plants and animals. Imagine yourself on an island where none of the plants and animals is known to you. Suppose that you wished to classify these living things. You might group them as useful or useless organisms if your own uses were the only factors to be considered. But such a classification would soon prove unsatisfactory, and you would seek another. You would soon observe that some animals live in the water, some on land, and some in the air. Therefore you might group them as land animals, water animals, and air animals if you needed to consider only their habitats. You probably would soon observe, however, that some of the animals in each habitat move from one habitat into the other. Then you would need to change the plan of classification again, for it would be a poor classification that required a change of grouping whenever an animal moved from one region into another.

You would need to find some better basis of classifying the animals on your island. You might observe great differences among the animals in each of the regions named above. Thus some of those in the water would have fins and no legs. Others would have shells and no fins. Still others would have no fins, legs, or shells, but would crawl on the mud at the bottom of the water. To say that they were water animals might not always be true, and would not give much information about them, except that sometimes they might be found in the water.

A more satisfactory way to classify animals would be to make a group of those that have similar body structures. On your island you might place in one group all that were covered with scales and that used fins for locomotion. You might place in another group all that had feet and feathers and that flew in the air. In this way you could group together all animals that appeared to be related in their structures. The modern plan of classification is based on this principle.

You would probably give names of some sort to the animals on the island. You might call one "that swift little animal with gray fur and a long tail." But if you were to talk about this animal, you would soon find that a shorter name would be much more convenient. Your experiences would be the same

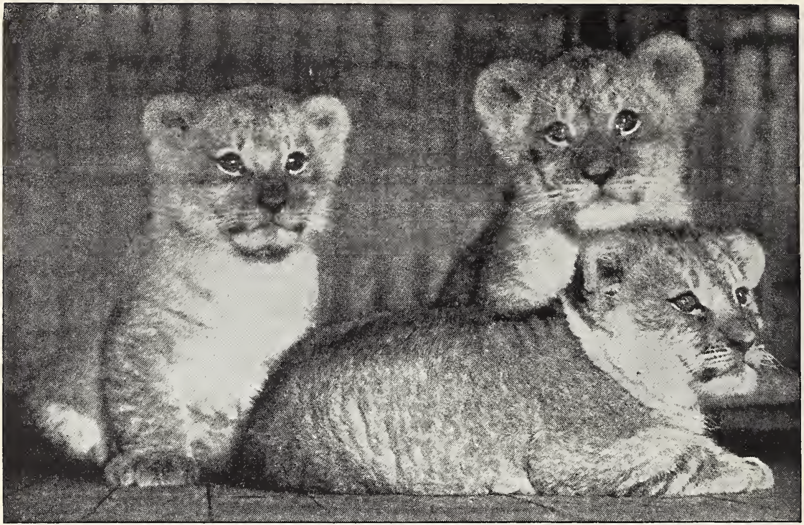
A. M. N. H.

Lizards of the Galápagos Islands. If you should discover such creatures as these, how would you determine what kind of animals they are? A trained scientist, by examining their structures, would be able to classify them

as those of scientists in finding a way of naming plants and animals for scientific study. The first scientific names given were long and consisted of many terms describing the organisms.

Possibly you would decide to use a shorter name for the animal, as "long-tailed mouse." This name might serve well enough until you discovered that people on a neighboring island used exactly the same name for an entirely different animal. Common and local names for animals and plants have indeed come to mean such different things in different places that scientists do not depend on them. Gopher in one part of the United States is a small furry animal with pouched cheeks. In another part it is a land tortoise. In still another part it is a snake. In different parts of the United States the goldfinch is called the wild canary, the thistle bird, and the golden warbler. Moreover, the names of common plants and animals are certain to vary even more in different countries. For example, the word meaning "dog" is *chien* in France, *Hund* in Germany, *perro* in Spain, and *go* in certain parts of China. Common names are desirable only when it can be certain that they will be understood.

*We must invent names, therefore, which students in all parts of the world can recognize as belonging only to certain kinds of plants and animals. The necessity for such a scheme of naming was recognized long ago. Many plans for classifying and naming plants and animals were suggested and rejected before the present plan of scientific classification was devised. This plan has



Newton H. Hartman

Two-month-old lion cubs of the Philadelphia zoo. Can you name any other animals to which you think the lion is probably related?

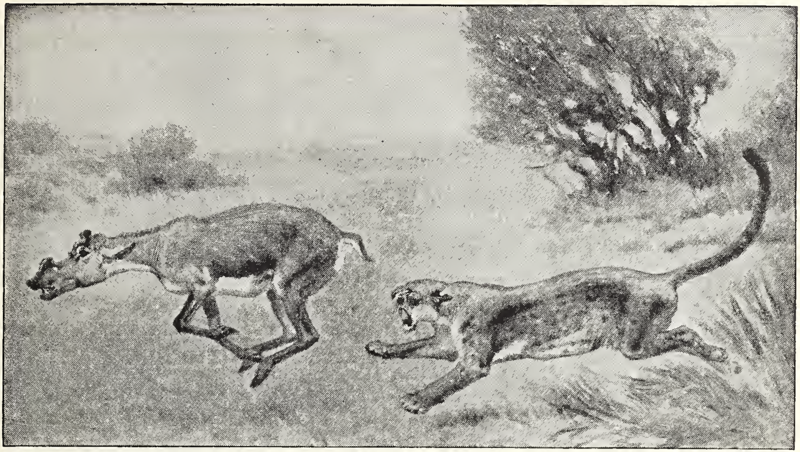
been built up through careful study of the likenesses and differences in the structures of animals and plants. The names now used serve as a scientific language among all nations in much the same way as do chemical symbols.

The plan of classification. There are many different breeds of dogs, such as collies, Saint Bernards, greyhounds, poodles, and terriers. But, different as they are, they are all dogs; and one readily recognizes them as such. They are all of the same species; that is, all are of the same special kind of animal. A *species* is therefore defined as a group of closely similar individuals.

Dogs are closely related to wolves, coyotes, and jackals. Dogs, wolves, coyotes, and jackals, therefore, all belong to the same genus. A *genus*[1] (plural *genera*) is defined as a group of related species. It is easy to see the likenesses of dogs, wolves, coyotes, and jackals. It is not easy, however, to see likenesses in some other genera.

Every animal or plant has a scientific name of two parts. The first, which begins with a capital letter, indicates the genus. The second, usually beginning with a small letter, indicates the species. Scientists have agreed that the genus and species names should always be in Latin. This agreement was made because at the time this system of names was adopted Latin was

[1] See the Glossary for the pronunciation of scientific terms.



A. M. N. H.

These animals lived many centuries ago in North America. What present-day animal is each most like?

the common language of scholarly people. Thus any dog is known to scientists as *Canis familiaris*; any wolf, as *Canis lupus*; any coyote, as *Canis latrans*; and any jackal, as *Canis aureus*. *Canis*, then, is the genus name, and *familaris*, *lupus*, *latrans*, and *aureus* are the species names. This very simple way of naming plants and animals by two names was invented by a Swedish botanist, Carolus Linnaeus, and was perfected by him about 1750. It came into general use in the ten years that followed. It is called the binomial (that is, two-name) system of naming plants and animals.

Making larger groups. In building the system of classification, a number of similar genera are put together in one *family*. For example, the various genera of dog-like animals are all grouped into one family, the Canidae. Similarly the various genera of cat-like animals, such as the house cat, the lion, the tiger, and the leopard, are all put into one family, the Felidae.

The fourth step in the system of classification is to find characteristics of structure which a number of families have in common. One such characteristic is the structure of the teeth and jaws, which has to do with methods of securing food. Therefore all families having teeth and jaws of the same type are grouped into an *order*.

Thus the dog family, the cat family, the weasel family, and other animals of prey together make up the order of Carnivora, which means the flesh-eaters. The squirrel family, the rat family, the rabbit family, and all other families of animals that gnaw make up the order Rodentia.

The fifth step in the system of classification combines different orders. A dog is not much like an elephant or a horse; yet it is more like those animals than it is like a chicken or a snake. One characteristic which dogs, cats, horses, and elephants have in common is the possession of special glands which produce milk for their young. Therefore all orders of animals having this characteristic are grouped together. Such a group is called a *class*. The orders having milk glands make up the class called Mammalia or, more commonly, mammals. Other classes are the Aves, which includes the animals with feathers, that is, the birds; the Reptilia, which includes the snakes, lizards, crocodiles, and others; the Pisces, which includes the fish. There are other classes that need not now be listed.

Dogs, fish, birds, and snakes are not much alike; yet they are more nearly alike than they are like insects, worms, or starfish. All the Mammalia, Pisces, and Reptilia have spinal cords, while snails, sponges, worms, and insects do not. Hence all the classes of animals having spinal cords are grouped together and are called Chordata. Similarly all the classes of animals having one-celled bodies are grouped together and called Protozoa. Such a large grouping together of many classes is called a *phylum* (plural *phyla*).

The final step in constructing the scheme of classification consists in grouping the phyla into two great kingdoms of living things—the plant kingdom and the animal kingdom. In the plant kingdom there are four phyla. In the animal kingdom ten phyla are usually recognized. These ten phyla do not include all the animals, though they include the most important ones.

Summary of the plan. *Every animal and plant can be classified according to the plan as outlined. The various groups in this scheme of classification have been built up through a study of the differences and likenesses in the structures of plants and animals. Therefore the scheme shows the relationship of one group to another with respect to structure.

*The divisions in order from largest to smallest are kingdom, phylum, class, order, family, genus, and species. To illustrate the complete scheme of classification a chart has been prepared to show the classification of the dog, the wolf, the cat, man, the robin, the red-legged grasshopper, and the common dandelion.

*In common use, only the names of the genus and the species of an organism are given. Such a name as *Felis domestica*, the cat, or as *Lilium canadense*, the Canadian lily, means a particular kind of animal or plant, and will not be confused with any other. We do not usually make much use of these scientific names in our ordinary conversation. The biologist, however, could not carry on his work effectively without such accurate names for the living things of which he speaks. Also, the public press now uses some of these

Kingdom .	Animal	Animal	Animal	Animal	Animal	Animal	Plant
Phylum . .	Chordata	Chordata	Chordata	Chordata	Chordata	Arthropoda	Spermatophyta
Class . . .	Mammalia	Mammalia	Mammalia	Mammalia	Aves	Insecta	Dicotyledoneae
Order . . .	Carnivora	Carnivora	Carnivora	Primates	Passeres	Orthoptera	Campanulales
Family . .	Canidae	Canidae	Felidae	Hominidae	Turdidae	Locustidae	Compositae
Genus . . .	Canis	Canis	Felis	Homo	Planesticus	Melanoplus	Taraxacum
Species . .	familiaris	lupus	domestica	sapiens	migratorius	femur-rubrum	officinale

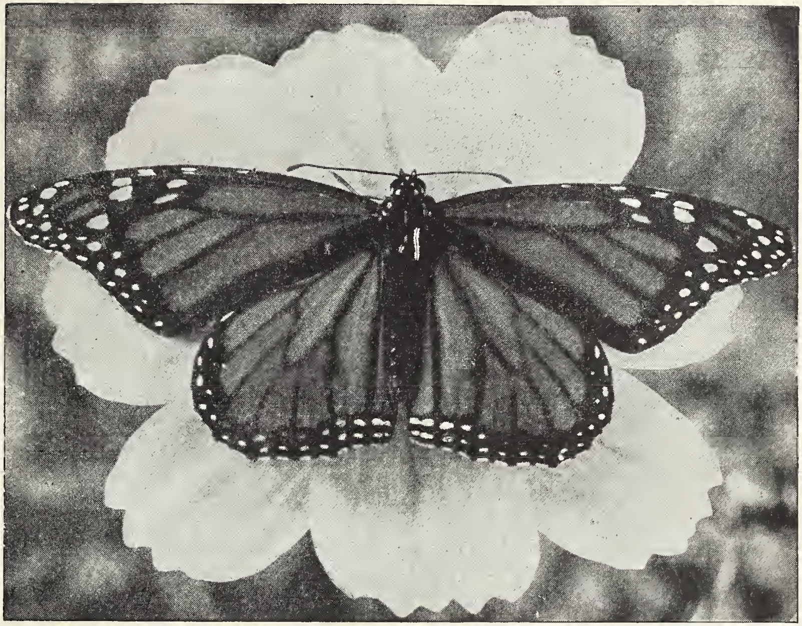
Chart showing how living things are classified. On this chart the differences between the dog and the wolf do not appear until the species is reached. At what point should you expect the classification of a fox and of a fish to differ from that of the classification of the animals named here? Does the fir tree or the lily belong in any of the groups in this chart? Explain names, and they are becoming more and more commonly used by educated persons in their writings and discussions.

How biologists use the system of classification. Suppose a biologist were to find an insect not known to him. From his general studies he would know at once that the organism belonged to the animal kingdom, the phylum Arthropoda, and the class Insecta. There are, however, more than four hundred thousand known species of insects, and some have not yet been named. How could the biologist find out the genus and the species of his specimen?

First he would collect a large number of specimens of the insect. Then he would make a careful study of its structure, its food, and its habits. When entirely certain of the facts from a careful study of many specimens, he would be ready to use his insect "key." A key is a book in which the characteristics of each phylum, class, order, family, genus, and species, so far as they are known, are described completely and accurately. Keys have been prepared by biologists for all classes of organisms. When in the preceding sections we discussed the way in which a system of classification has been built up, we began with the species and ended with the phylum. In keys, however, this procedure is reversed. Thus the scientist would begin with the phylum and end with the species. By comparing the characteristics which he had discovered as belonging to the unknown insect with the characteristics described in his key, he would be able to trace the insect through the key. He would first find the order to which it belongs, next the family, then the genus, and at last the species.

If after careful comparison with the key the biologist should find that his specimens are unlike all the species described, he might conclude that his specimens are of a species of insect that is not listed in the key. His specimens might be those of an insect not yet known to science. If sure that he is right, he might announce his discovery to the scientific world.

Immediately other biologists would attempt to secure specimens of the new insect. Each would classify it himself in order to make sure that the first biologist's classification was accurate. If they all reached the same conclusion, they would approve the announcement of the insect as representing a new species. The discoverer would add to the genus name, which we assume was already known, a new species name to designate the species he had discovered. This name might be a Latin form of the name of the discoverer, as a mark of special honor, as *jonesi* (discovered by Jones); or it might be a Latin form of the name of the locality in which the new species was found, as *canadensis* (found in Canada); or it might be a word which described the species, as *alba* (white). The name of the new insect would then be added in its proper place in the insect keys for future use.



Lynwood M. Chace

Monarch butterfly (*Danaüs archippus*) on cosmos (*Cosmos bipinnatus*). The common name may be either like or very different from the scientific name. Should you expect the moth to belong to the same species, genus, family, order, class, and phylum as the butterfly? Justify your answer

Self-test. 1. All living things are classified on the basis of likenesses and differences in their *habits.*

2. The scientific name of any organism consists of *three Greek* names.

3. Name in order of smallest to largest these groups: kingdom, class, order, phylum, species, genus, family.

4. The scientific name of an organism indicates the *phylum* and the *order.*

Self-test on Important Biological Terms

class
classification
family

genus
kingdom

order
phylum
species

ADDITIONAL EXERCISES AND ACTIVITIES

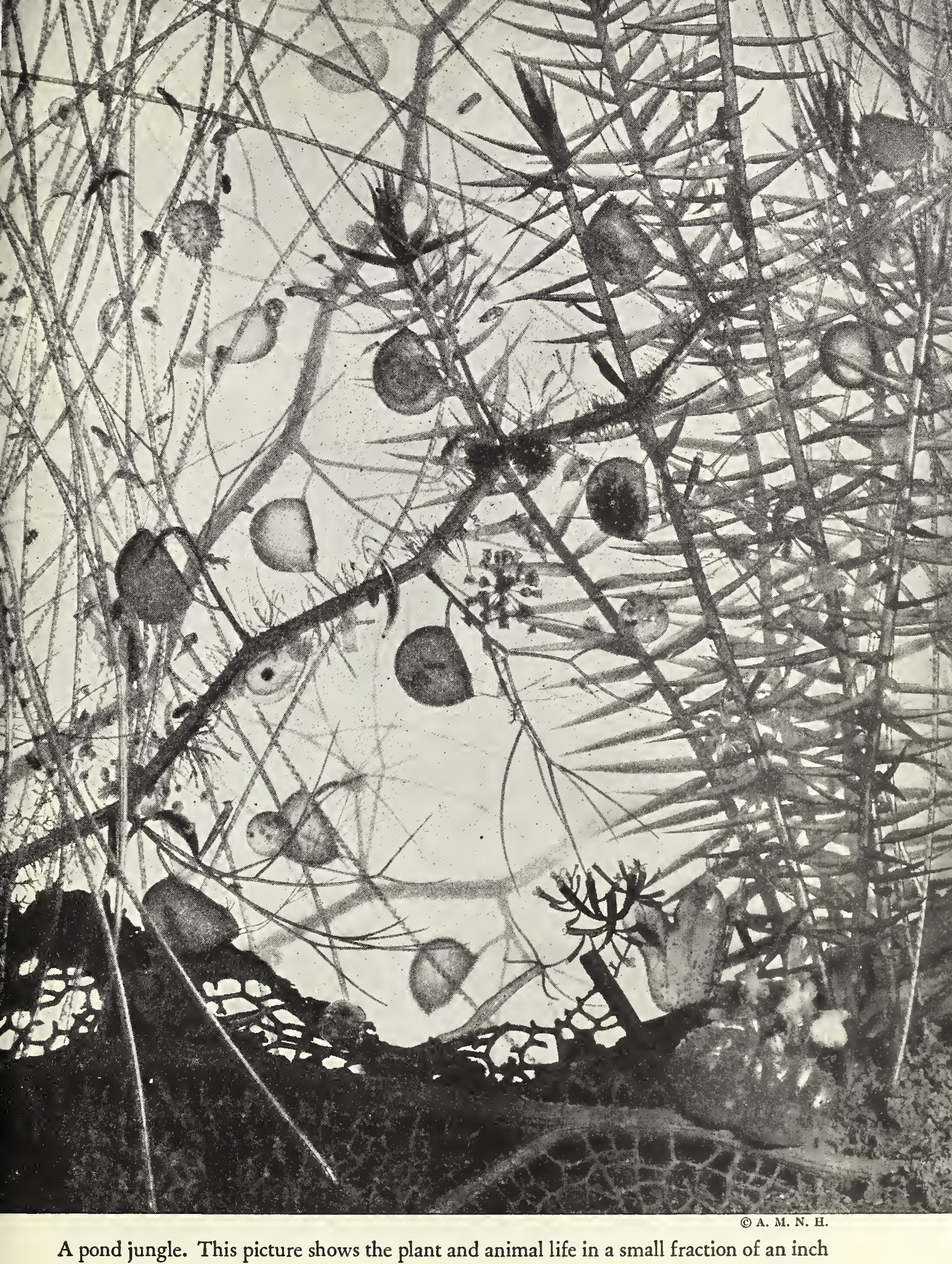
Problems. 1. Make a table similar to the one on page 123, classifying several organisms, as the horse, the lion, or any others. Dictionaries and encyclopedias will give much information. But you will sometimes have to leave blank such items as family and order, which are difficult to find.

2. The following key will enable you to identify a few of the common native evergreens. This key is introduced here to give you practice in using a key. It includes all genera but not all species of native cone-bearing trees. Use the key to identify such specimens as you can find.

A. Leaves needle-like, always present; evergreen
  B. Leaves in clusters of 2 or more
    C. Leaves in clusters of 5 in a sheath. White pine (*Pinus strobus*)
    C. Leaves in clusters of 2 (occasionally 3)
      D. Leaves 4 to 6 inches long; cones on the ends of branches. Red pine (*Pinus resinosa*)
      D. Leaves very short and thick; $\frac{3}{4}$ to $2\frac{1}{2}$ inches long. Jack pine (*Pinus banksiana*)
      D. Leaves 3 to 5 inches long; cones on the sides of branches. Yellow pine (*Pinus echinata*)
    C. Leaves in clusters of 3 (rarely 2 or 4)
      D. Leaves 3 to 5 inches long; cones often in clusters. Pitch pine (*Pinus rigida*)
      D. Leaves 10 to 16 inches long. Long-leaved pine (*Pinus palustris*)
  B. Leaves single
    C. Opposite
      D. Fruit, a cone; leaves flat, scale-like. Arbor vitae (*Thuja occidentalis*)
      D. Fruit, a berry; leaves needle-like and scale-like. Juniper (*Juniperus communis*)
    C. Not opposite
      D. Leaves four-sided, scattered thickly on the twigs. White spruce (*Picea canadensis*)
      D. Leaves flat
        E. With a short petiole. Cones bright red-brown. Hemlock (*Tsuga canadensis*)
        E. Without a petiole. Cones dark purple. Fir, or balsam (*Abies balsamea*)
A. Leaves needle-like, deciduous
  B. Leaves many in a cluster. Tamarack, or larch (*Larix laricina*)
  B. Leaves single, alternate. Bald cypress (*Taxodium distichum*)

Exercise on Scientific Attitudes. Which of the scientific attitudes stated on page 624 are illustrated in the description (on page 124) of how a biologist classifies a strange specimen?

Exercise on Scientific Method (Using Controls and Check Experiments). Why was it necessary for the scientist to secure a number of specimens as the basis for classifying his insect?



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A pond jungle. This picture shows the plant and animal life in a small fraction of an inch of a pond. The objects, many of them algae, are magnified more than one hundred times. In what sense are these plants engaged in the struggle for energy? The cap-shaped bodies are the traps of carnivorous, or flesh-eating, plants which capture tiny swimming animals. Many simple algae are seen attached to the large plant stems

CHAPTER IX

The Four Great Groups of Plants[1]

Questions This Chapter Answers. 1. What are the four plant phyla? · 2. What are some characteristics of algae, bacteria, yeasts, molds, and mushrooms? · 3. How do mosses and their relatives differ from other plants? · 4. What are some characteristics of the ferns and their relatives? · 5. What are the differences between two great groups of seed-bearing plants? · 6. What are the chief distinguishing characteristics of the two great groups of flowering plants? · 7. What are important functions of the structures found in the various groups of plants? · 8. Of what importance to man and to other organisms are the various groups of plants?

WHAT ARE SOME ADAPTATIONS OF THE SIMPLEST PLANTS[2] WHICH ENABLE THEM TO LIVE SUCCESSFULLY?

The plant kingdom. The plant kingdom is far larger than the animal kingdom. It contains enormously greater numbers of organisms, although not so many different kinds. It contains the living things which directly and indirectly supply all the food in the world and without which, therefore, all life would soon disappear from the earth. Included in it, also, are both the largest, and probably the smallest, things that ever lived. It contains many of man's most dangerous enemies, as well as many of the living things which are most useful to him. It contains organisms that can live at higher temperatures and others that can exist at lower temperatures than any members of the animal kingdom can endure. Moreover, it is believed by many scientists to contain the first living things that appeared on the earth.

The four plant phyla. *The plant kingdom is divided into four great groups, or phyla. In almost any woodland one may find examples of all these phyla. The first phylum includes the algae and the fungi. Common algae are the pond scums. These are found growing as tangled masses of green threads, sometimes attached to stones, logs, and other objects in streams and lakes. They are also sometimes found floating on the surfaces of ponds and lakes, on the surfaces of streams near the banks, and in the oceans. Fungi include such familiar plants as molds and mushrooms. Most fungi are simple in structure and small in size.

*The second phylum includes a great variety of liverworts and of mosses. Among these are the familiar plants which sometimes form a soft carpet on the hillsides or about the roots of trees.

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[1] To THE TEACHER. In presenting a general description of the leading groups of plants and animals, it has proved effective to include only those general aspects that are necessary in gaining a clear idea of each group. More detailed discussions of life processes are given in later chapters.

[2] Phylum Thallophyta.

Drawing of *Pleurococcus.* Can you use the phrase "struggle for survival" in explaining why *Pleurococcus* is a successful plant?

*The third phylum is made up of the ferns and their relatives. In this group are some of the most beautiful of all the plants, though none has flowers.

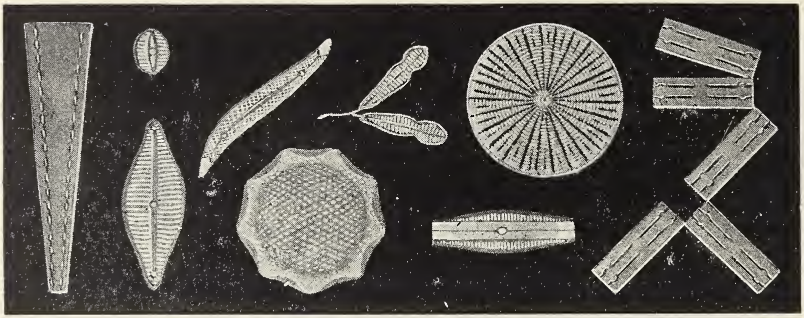
*The fourth and highest phylum includes all the flowering plants, such as the wild flowering plants, the grasses, and the trees. We are probably familiar with more members of this phylum than of the others because these are generally the largest and most conspicuous plants.

The simplest plants. *The simplest plants (phylum Thallophyta) do not possess roots, stems, or leaves. They have no flowers, and they do not produce seeds. Some of them, the algae, have chlorophyll and can make their own food. Others, the fungi, lack chlorophyll, and therefore must live as either parasites or saprophytes. Although most of the plants of this phylum are small, a few kinds are large. Thus they vary in size from microscopic bacteria to certain sea algae (kelps) that are sometimes of greater length than the height of the tallest tree.

Algae. Algae are commonly found in ponds and streams and in moist places on trees or rocks. The green substance which collects on the inside of fish tanks may include several species of algae. Other species of algae, usually called sea-weeds, grow in the oceans.

Some of the algae consist of single cells or masses of cells. Others are made up of groups of cells arranged in long ribbon-like filaments, or threads. The fresh-water forms are green or blue-green in color. Many of the salt-water forms, however, contain so much brown or red coloring matter that their green chlorophyll does not show. Some of these sea algae are strikingly beautiful.

In shaded moist places on the sides of trees, buildings, and rocks one may see patches that look like green paint. These patches are made up of algae of a very simple kind (*Pleurococcus*). Each one of these microscopic plants is a single cell and is independent of its neighbors. These plants are visible only when large numbers of them are massed together. This plant makes its own food by photosynthesis. In spite of its small size, this alga is a very



Algae with outside skeletons. Find one of these diatoms in the pond jungle, p. 127

successful plant; for it is found in all parts of the world, even in the frozen wastes of the polar regions where few forms of life are able to survive.

Experiment 24. What is the appearance under the microscope of some of the thread-like algae? Collect some pond scum from a pond or quiet stream. From a study of the color, place and manner of growth, and other characteristics do you judge that you have found more than one kind? Examine your specimens through the microscope. Note the long cells placed end to end to form the filament. What is the arrangement of the chlorophyll bodies? (The arrangement is different in each kind of alga.) Probably you have collected some *Spirogyra,* in which the chlorophyll is found in a spiral band (see the figure on page 551). Are all the cells in each filament alike? Sketch or describe briefly the differences in the various filaments you observe.

In thread-like algae every filament is made up of a single line of cylinder-shaped cells which are attached to one another at their ends. The cells are entirely independent. Therefore the filament may be broken apart without killing the individual cells.

One-celled plants do not, as a rule, have any sort of skeleton, though the cell wall of most species maintains a fixed shape. Certain single-celled algae (diatoms) do, however, have a hard (siliceous) protective covering.

Importance of the algae. In addition to the large sea-weeds, or kelps, microscopic algae in countless numbers are found on the ocean surface and as far below the surface as the sunlight can enter. A single quart of sea water has been found to contain more than six million individual algae. These plants serve directly and indirectly as food for the animal life in the sea; for they are eaten by microscopic animals and these in turn by fish, which then become the food of still larger creatures. The ocean algae, together with the fresh-water forms, not only furnish food for aquatic animals, but also by the process of photosynthesis give off oxygen to replace that used by animals in breathing. Certain of the sea-weeds are prized by man as food. The Japanese grow them in the warm waters of shallow seas. Agar-agar, which is obtained from a sea alga, finds wide use as a substance on which to grow bacteria in the laboratory and sometimes as a remedy for constipation. Certain sea algae are used as a source of iodine and potassium. However, most of the iodine now used is obtained by chemical processes. At times the algae which grow in city reservoirs may give a disagreeable taste to the water.

Fungi. *The fungi are all dependent plants, such as bacteria, yeasts, molds, mushrooms, rusts, rots, blights, and smuts. In spite of the small size of most of them, the plants in this group are of great economic importance. Many of them cause diseases in plants and animals. Others are of use to man in various ways which will be discussed later.

Bacteria. *Bacteria (singular, bacterium) are the smallest known plants. None of them can be seen without a microscope, and it is believed that there are many too small to be seen with any microscope yet invented. Of the smallest that can be seen, it would take about twenty-five thousand, end to end, to make a line an inch long.

Bacteria are found almost everywhere. They are so small that they can float in the air with particles of dust. Water usually contains great numbers of them. The upper layers of moist soil also are rich in bacterial life. Many of these bacteria are saprophytes. Such bacteria feed on the bodies of dead animals, on dead leaves or decaying roots, or on plant and animal wastes.

*Bacteria will grow rapidly wherever there are food material, moisture, and neither too high nor too low temperature. They reproduce by dividing in two. If conditions are favorable, they may divide every twenty or thirty minutes.

Experiment 25. Where may bacteria be found? How do they develop? Prepare a culture medium; that is, prepare material which bacteria can use as food and hence on which they will grow readily. To 200 cubic centimeters of water add 3 grams of agar-agar and 1 gram of beef extract. Boil the mixture until the agar-agar is dissolved. Strain through cotton into a flask. Sterilize[1] the mixture again by boiling it and, if the mixture is not entirely clear, strain again. Pour into sterilized test tubes or Petri dishes, cover immediately, and let stand until cool. Set one dish aside unopened as a control.

Expose other dishes or tubes (1) to the air of the room for three minutes; (2) to the air out of doors; (3) to dirt from the floor or table; (4) to contact with a dirty finger; (5) to a drop of water; (6) to a drop of milk; (7) to contact with the end of

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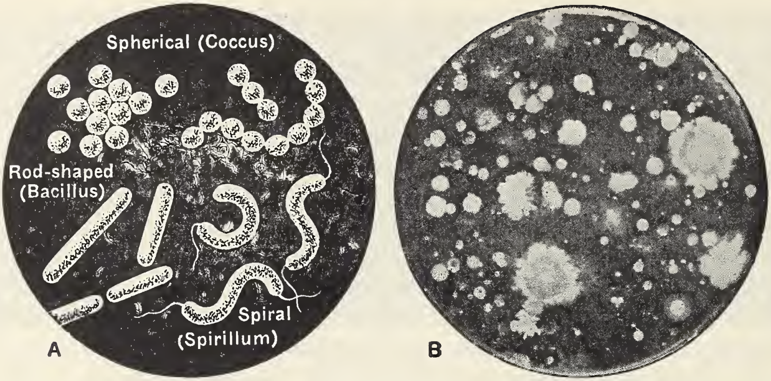
[1] *Sterilize* (stĕr′ĭ līz): to destroy all germs in a space, in a substance, or on a surface.



A, The three types of bacteria; *B,* colonies of bacteria. Probably not all these colonies are bacteria. Can you suggest what some of the others may be?

a toothpick which has been used in removing tartar from the teeth; (8) to as many other places where bacteria may be found as you like. Cover the dishes and set them in a warm dark place for several days. Examine from day to day. How soon do the first spots, or colonies of bacteria, appear? Are they all of the same color? Make a sketch of one or more plates similar to that in the figure, showing the shape and size of the bacterial colonies.

Explain how the unopened dish serves as a control (see "Elements of Scientific Method," p. 625) and why a control is necessary. Why were all the dishes put in the same place while the colonies were developing?

*As a rule, bacteria thrive best in darkness. A few known varieties, however, use mild sunlight as the source of energy to perform important life processes. But direct sunlight, as well as high temperatures and certain germ-killing substances called antiseptics, or germicides, kill most of them in a short time. Even those that produce spores[1] are killed by exposure to sunlight for a few hours.

The temperature at which growth and reproduction are most rapid varies with the particular kind of bacterium, but is usually from 20° C to 40° C. Low temperatures check the growth of bacteria. Some forms, however, are able to remain alive at extremely low temperatures. Most forms are killed at the boiling temperature of water (100° C).

Every bacterium consists of but one cell, though often many bacteria are found joined together to form what is called a colony. Each bacterium, however, whether by itself or one of a numerous colony, must carry on all the life processes in order to live. It must get food, take in oxygen, get rid of wastes, grow, and reproduce.

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[1] *Spore:* a resting stage in which the protoplasm is enclosed in a thick wall and is thus able to exist during unfavorable conditions of temperature and dryness.

Useful and harmful bacteria. *Bacteria cause many of the diseases of plants and animals, including man. For this reason we are inclined to think of their activities as being only harmful to man and his work. This is not the case. More than a thousand kinds of bacteria are now known. Of these only a few are parasites of man and the other higher animals, and still fewer can cause disease. Most of the rest are harmless. Some are definitely useful.

Many bacteria feed on the dead bodies of animals and plants, causing them to decay and thus fertilizing the soil. Certain kinds of the bacteria of decay are used in some of the industries. In the sponge industry, for example, the decay bacteria eat the softer tissues from the skeletons of the sponges. In the tobacco industry decay bacteria help in curing the leaves. In the flax and hemp industries decay bacteria eat the softer portions of the plant stems, leaving the tougher fibers, which are used. In the dairy industry certain bacteria help in the preparation of butter and cheese. Still other bacteria aid in the cider and vinegar industry. It is perhaps not often realized that the special ("gamy") flavor which many people enjoy in meat and the delicate flavors of butter and certain cheeses are due to the beginning stages of decay.

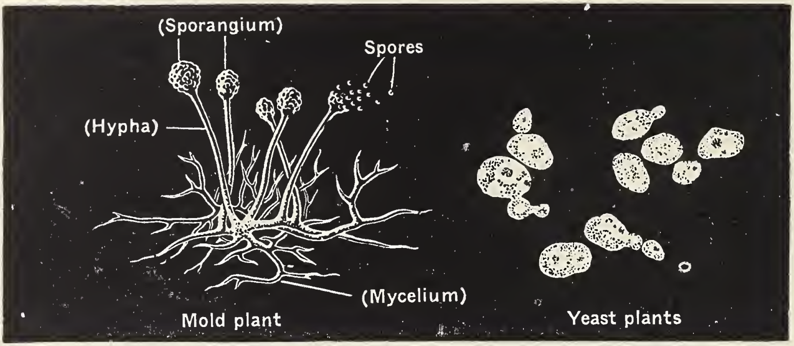
Certain bacteria are useful in purifying human wastes, or sewage. These bacteria cause oxidation of organic wastes and thus make them harmless.

The harmful bacteria, aside from those which produce diseases, are chiefly those which eat our foods and thus compete with man for the available supply of energy. They sometimes produce substances which give the food an unpleasant odor or flavor or which in some cases may make the food poisonous.

Yeasts. *Yeasts are single-celled plants considerably larger than bacteria, yet not large enough to be observed without the aid of a microscope.

Experiment 26. What is the appearance of the yeast plant? Dissolve a compressed yeast cake in a cup of water to which a tablespoonful of sugar has been added. Let it stand overnight in a warm place. Prepare a slide of a drop of the solution and examine it under the microscope. Compare the yeast cells you observe with those in the figure on this page. Make a sketch of some of the single cells and groups of cells.

The yeast plant uses sugar as its chief source of food. The sugar is changed by the yeast to alcohol and carbon dioxide. This action is called *fermentation.* Alcoholic drinks, some of which have a definite place in medicine, are produced by the fermentation of fruit juices and of sugars produced from certain plants and grains. Bread is made light by the carbon dioxide which is given off during the process of fermentation in the dough.



In what sense do mold plants and yeast plants compete with man for food?

Yeasts do some damage when they cause fermentation in such foods as jellies, preserves, canned fruits, and sirups. The activities of yeasts sometimes produce a bitter taste in cheese and milk.

Molds. *Molds are larger and more complex than the other fungi we have studied. They are many-celled plants, composed of long filaments of cells. This mass of filaments (mycelia) usually extends deep into the food substance on which the mold grows. Molds are of great importance for several reasons: (1) Some varieties aid in the decay of wood and other substances. Thus they make the material available as foods for other organisms. (2) Others compete with man for food. Not only do they slowly consume it, but some species also give it an unpleasant odor or flavor or an unpleasant appearance. (3) Other molds impart desirable flavors to certain cheeses. (4) Still a few others cause diseases of man and of some of the other animals.

Experiment 27. What are the parts of a mold plant? Examine with a magnifying glass a piece of bread or a culture or agar-agar upon which mold is growing. Note the filaments (hyphae), at the ends of which are the spore cases (sporangia), containing the spores. Examine the spore cases to see whether you can find any of the tiny spores. Carefully separate the bread or the agar-agar culture to see whether you can learn what the parts of the mold beneath the surface are like. Make a sketch showing the parts of a mold plant.

Relation of fungi to the preserving of food. Bacteria, yeasts, and molds cause most of the spoiling of foods which man stores for future use. Knowledge of the conditions under which they thrive enables him to make their growth in food difficult or impossible. Thus, in canning food, the living organisms in the food are first killed by heat. The can is then sealed so that living cells cannot enter. In drying food, water is evaporated from the food, which is then kept so dry that fungi cannot multiply in it. In salting food, the fungi are mostly killed because the salt causes osmosis of water out of the cells. In pickling food, substances are added which are harmless to human beings, but which prevent the rapid multiplication of fungi.

Mushrooms. Among the largest and most complex of the fungi are the mushrooms. They are common in woods and fields. There they grow as saprophytes on decaying wood and on decaying vegetable matter in the soil. A few grow as parasites on living trees.

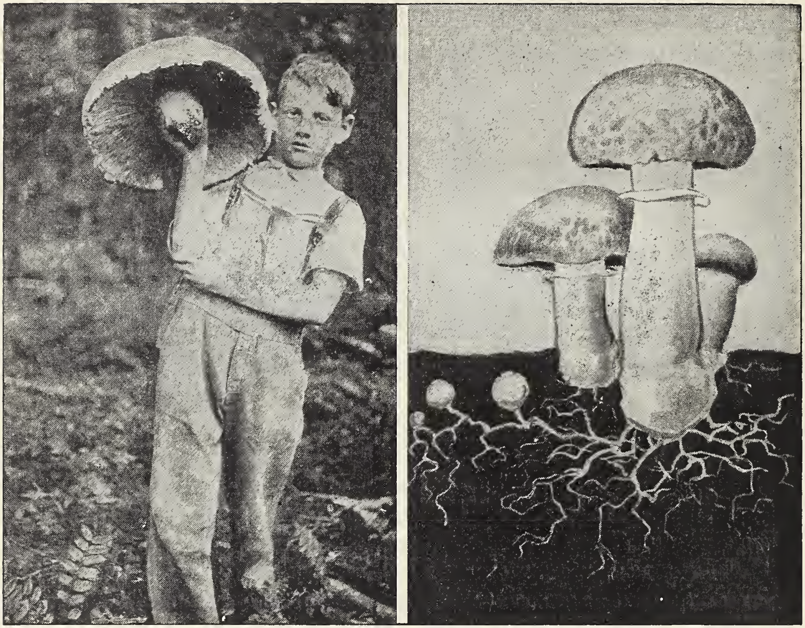
The real body of the mushroom is made up of a network of small threads, or filaments (mycelia). These extend through all portions of the food material. The part of the mushroom above ground produces and scatters the spores, from which the new mushroom plants grow. In most of the mushrooms that have expanded caps at the top of the stalk, the spores are borne on folds of tissue or in pores under the cap. In the puffballs the spores are produced inside the plant.

A drawing of mold plants made by Robert Hooke about two hundred fifty years ago. **Special Report:** Consult an encyclopedia for facts concerning Hooke and his work

Some mushrooms are prized as food, while others are more or less poisonous. A few are deadly. There are no entirely reliable tests which can easily be used to determine which are edible and which are not. It is safe to eat only those which one *knows* to be wholesome. There is grave danger in eating any others. The commercial mushrooms are of but a few kinds, each known to be wholesome.

Important relatives of the mushrooms are the bracket fungi, often found as shelf-like growths on trees. These forms become hard and woody, and may live for many years, growing very large. They are either parasites or saprophytes, and do considerable damage to living trees and to fallen timber.

Lichens. Lichens are interesting plants belonging to this phylum (Thallophyta). Common forms may be found on trees or rocks, as crust-like patches. A lichen is really two plants living together. A network of fungus threads forms the main body of the plant. Scattered throughout this network are algae cells. The fungus serves to attach the plant, to secure water, and to protect the algae from drying out. The green cells of the algae manufacture



An edible mushroom (*Lentinus lepidus*)[1] and growing mushrooms. Can you explain how the mushroom develops?

food, which both they and the fungus cells use. Thus each plant contributes to the association. Such a relationship is an example of symbiosis.[2]

Lichens will grow in places where other plants could not live. They can exist on bare rocks and on sandy wastes. They help to break up the rock surfaces, thus forming soil in which other plants can later grow. "Reindeer moss," a branching lichen which may become several inches tall, is used as food by the reindeer in the Far North.

Self-test. 1. Name some of the kinds of plants that are included in each of the four plant phyla.

2. *Some* fungi have chlorophyll.

3. Algae are *dependent* plants.

4. *All* the food eaten by sea animals is made, directly or indirectly, by *fungi.*

5. The smallest known plants are *yeasts.*

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[1] From a photograph by William E. Sherwood. Courtesy of *Nature Magazine.*

[2] See the index for earlier reference.

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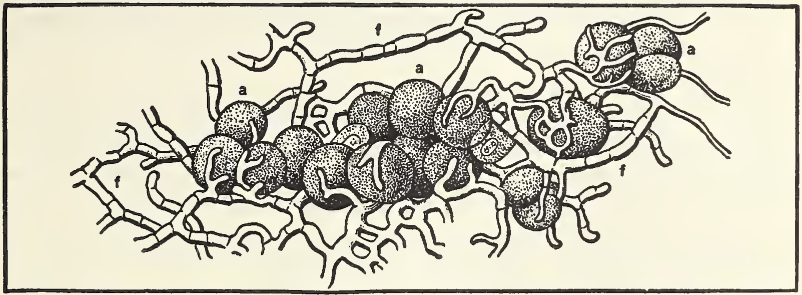

After Bonnier

Above, lichens on a rock; below, diagram of a piece of lichen, showing the association between the algae (a) and the fungus (f). Can you explain how the lichen furnishes an example of symbiosis?

6. *All* molds are *harmful.*

7. You can eat a mushroom with safety, provided (1) it peels; (2) you know that that species is good to eat; (3) it does not cause silver to turn black when it is boiled with the silver; (4) it has a pleasant smell; (5) it has a pleasant taste.

8. The conditions necessary for the rapid growth of bacteria are --?--, --?--, --?--, and --?--.

9. Man is aided in his struggle for survival by the activities of *all* bacteria.

10. *All* bacteria are independent plants.

WHAT ARE SOME ADAPTATIONS OF MOSSES AND LIVERWORTS[1] WHICH ENABLE THEM TO LIVE SUCCESSFULLY?

Mosses and liverworts. Mosses and liverworts make up the second phylum (Bryophyta) of the plant kingdom. They grow mostly on the ground, but many of them are found growing on tree trunks and dead logs. They are, however, all independent plants because they possess chlorophyll and make their own food by photosynthesis. They rarely become more than two or three inches tall. Many of the small mosses grow on rocks or in shallow soil that will not support larger plants. A few of the liverworts and mosses are also found in water. Many species grow only on very wet soil.

A common liverwort, found in damp shaded places, is a flat, dark green plant which looks like a leaf. On the under-side are root-like structures. These attach the plant to the soil and absorb water. Often so many of these plants are found growing in one spot that they form a solid mat on the ground or upon old tree trunks. Upright stalks for reproduction grow from the flat portions of such liverworts.

Experiment 28. What are the characteristics of a moss plant? Examine the plant to see whether you can discover stems, leaves, and the root-like hairs. Does your specimen have spore cases on the ends of stems? Record your observations by means of sketches.

*Mosses mark a stage in development above that of the algae and fungi because they have stems, small green leaves, and root-like hairs (rhizoids). These hairs anchor the plant and absorb moisture. In these respects mosses resemble higher plants. They lack, however, true veins to conduct the water through the stems and leaves. They differ also from higher plants in lacking woody tissue for support. Moisture passes by osmosis from cell to cell throughout the plant. Both mosses and liverworts reproduce by spores rather than by flowers and seeds.

Importance of mosses. *Mosses are important plants, especially in relation to soil production and conservation. They will grow on rocks to which a very thin layer of soil clings. Their root-like hairs force their way into the small pores in the rock, and as they grow they may split off small pieces of the rock. When the moss plants die, their decaying bodies are added to the soil. Thus, over a long period of years, the mosses may so change a barren rocky surface that larger plants will be able to live there.

Besides aiding in soil formation, mosses cover much of the floor of a forest with a heavy carpet. This covering prevents the earth from washing away and also lessens the evaporation of moisture from the ground. Certain of the

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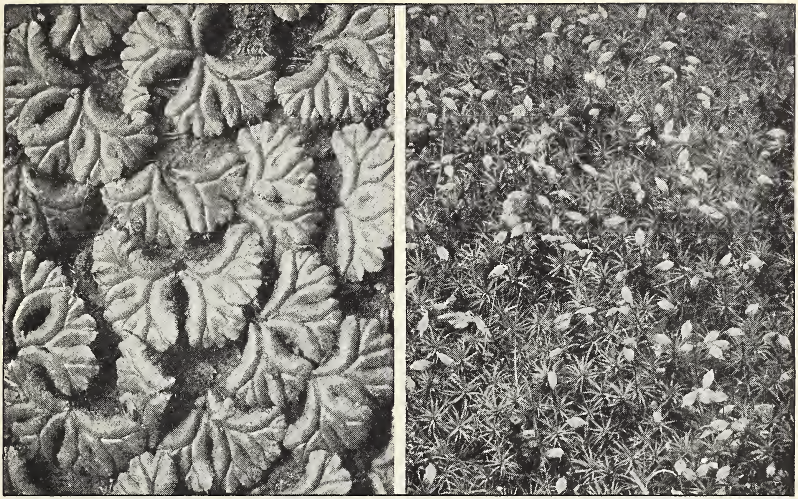
[1] Phylum Bryophyta.



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At the left, liverworts; at the right, moss plants. Is either of these plants a parasite or a saprophyte? Explain

mosses (peat mosses, or sphagnums) which grow in swampy places may finally fill up the swamp. Thus they may increase the available land surface on which other plants may grow. These mosses may form layers of peat, which, when dry, is used for fuel. It has been estimated that there is enough peat in the United States to supply the fuel needs for a century.

Self-test. 1. *Some* of the mosses and liverworts are saprophytes, and *some* are parasites.

2. Moisture passes from cell to cell in the moss by the process of __?__.

3. *Mosses* are of great importance as makers of soil.

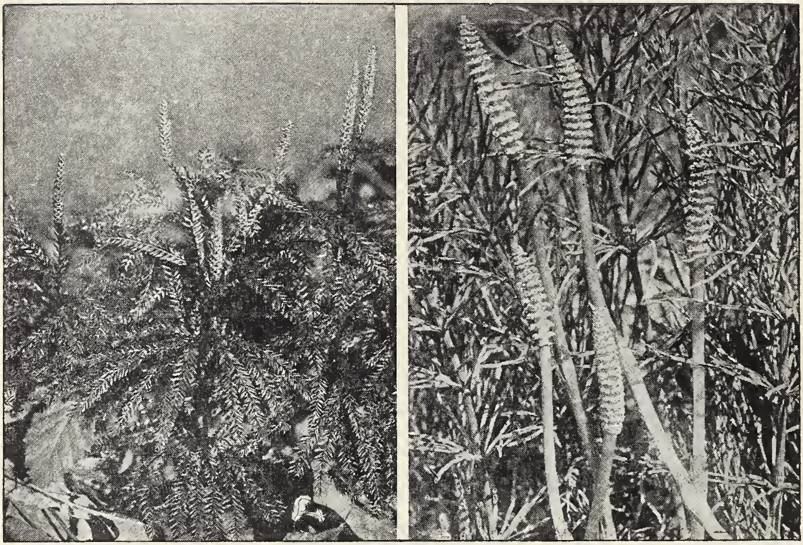
4. *Liverworts* are of great importance as a source of peat for fuel.

5. Three structures that indicate that mosses are higher in the scale of life than algae and fungi are __?__, __?__, and __?__.

WHAT ARE SOME CHARACTERISTICS OF THE FERNS AND THEIR RELATIVES[1] WHICH MAKE THEM SUCCESSFUL ORGANISMS?

The ferns and their relatives. *The ferns (phylum Pteridophyta) are larger and more complex than the mosses. They resemble the plants of the preceding phylum (bryophytes) in that they reproduce by means of spores.

[1] Phylum Pteridophyta.



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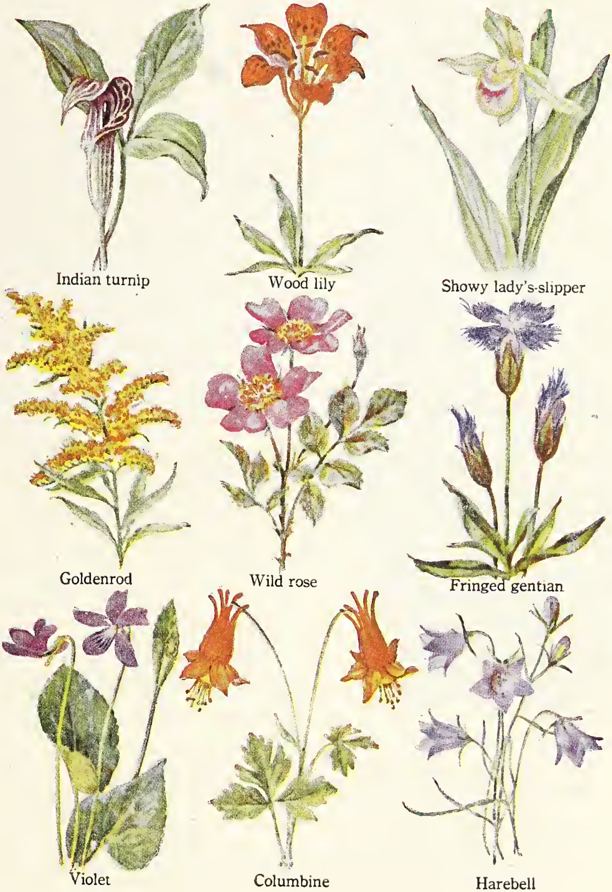
At the left, club moss; at the right, scouring rush. Can you name any relatives of these plants?

But they mark a stage of plant development above that of the liverworts and the mosses because (1) they have true roots, stems, and leaves, and (2) they have a simple vascular system.

The ferns and their relatives appeared on the earth before the flowering plants existed, and were very large and abundant. During the coal-forming period of the earth's history fern-like plants were the dominant type of vegetation. Huge tree ferns formed vast forests over parts of North America and Europe.

The three groups of this phylum which are commonly found in North America today are the ferns, the club mosses, and the horsetails (equisetums), also called scouring rushes. Ferns usually thrive best in moist woodlands or in swampy places where the soil is rich and deep. They vary considerably in form and can usually be distinguished from one another by characteristic differences in their feathery leaves. These leaves arise from stems (rhizomes) which are generally underground.

Common ferns of the Temperate Zones vary in size from small lowly plants to slender graceful plants six feet or more in height. In the tropics and in Australia tree ferns may reach a height of more than forty feet.



Indian turnip

Wood lily

Showy lady's-slipper

Goldenrod

Wild rose

Fringed gentian

Violet

Columbine

Harebell

Some common wild flowers

FROM A PAINTING BY F. SCHUYLER MATHEWS

The club mosses, sometimes called ground pines, are small graceful plants. The commonest genus (*Lycopodium*) is extensively used in decorations at Christmas time throughout the United States. In some states there are laws against its use because of the danger of its being exterminated. Fossil ancestors of club mosses with stems more than ninety feet long have been found.

The ancestors of the scouring rushes, or horsetails, were tree-like plants which flourished in great numbers ages ago. Only one genus (*Equisetum*) remains today. It is a jointed plant which grows in marshy ground, in sandy wastes, and along railroad tracks. It gets the name *scouring rush* from its hard, rough, glassy stem, which was formerly used in scouring cooking utensils.

Plants of the genus *Equisetum* vary in height from about eight inches for common varieties to about thirty feet for certain South American species. These latter kinds, however, are only an inch or so in diameter.

U. S. Department of the Interior

Giant ferns in Hawaii National Park. How do you explain the fact that tropical ferns are so much taller than those in the Temperate Zones?

Self-test. 1. The ferns, as well as the mosses, reproduce by means of *seeds.*

2. The fern plants grow from underground *roots.*

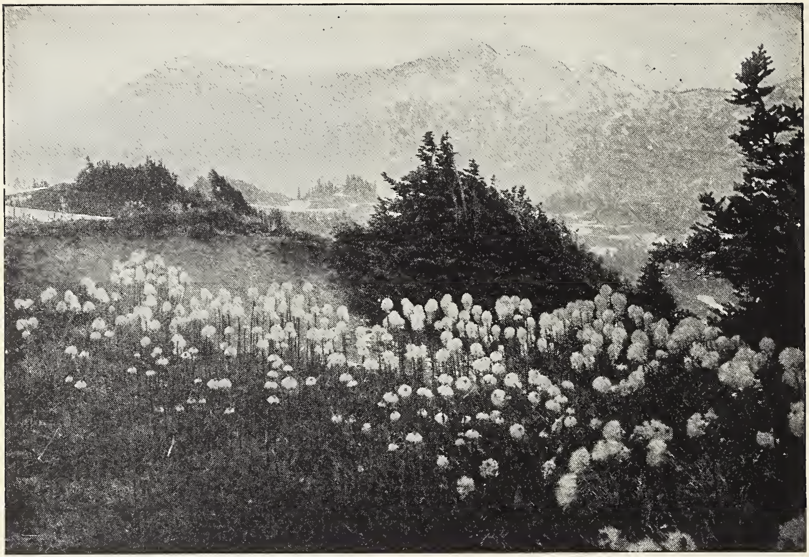
3. The ancient ancestors of the ferns and their relatives were *very small* as compared with the varieties now living.

4. One would expect ferns and their *relatives* to grow *larger* in Mexico than in Canada.

5. *Like* algae and fungi and *unlike* mosses and liverworts, ferns have roots and a vascular system.

6. The mosses and liverworts *have no* stems, leaves and roots like those of the ferns.

7. By means of their --?-- tissue, fern stems and leaves are able to become several feet high.



Asahel Curtis

Mt. Rainier National Park, Washington. Can you find examples of both groups of seed plants here?

WHAT ARE SOME ADAPTATIONS OF THE SEED-BEARING PLANTS[1] WHICH MAKE THEM SUCCESSFUL ORGANISMS?

The highest plants. *The plants which belong to the fourth phylum (Spermatophyta, or spermatophytes) differ from those of the groups previously studied in the fact that they all produce seeds. These plants are divided into two groups: (1) those (the gymnosperms) which have seeds that are usually borne in cones and (2) those (the angiosperms) which have seeds that are developed within certain parts of a flower and are enclosed in a pod, nutshell, or other case.

The first group (the gymnosperms) are largely cone-bearing trees. They are represented in North America by the pines, the spruces, the hemlocks, and the sequoias. Most of them are evergreens with needle-like leaves. The cones are of two sorts: (1) cones which produce pollen (staminate cones) and (2) cones which produce seeds (pistillate cones). Cone-bearing trees first appeared on the earth later than the giant-fern forests, and for ages were the dominant form of plant life. Today there are comparatively few species of them left.

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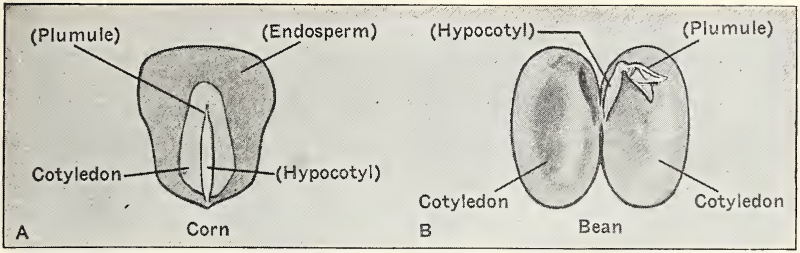
[1] Phylum Spermatophyta.



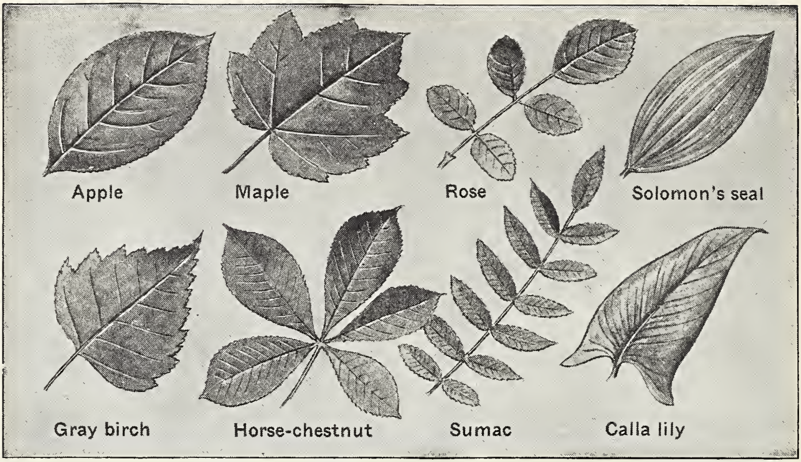
A, corn seed (monocotyledon); B, bean seed (dicotyledon). Compare these two seeds. (See "How to Study," p. ix)

The second group (the angiosperms) are the true flowering plants, in the sense in which the word *flower* is commonly used. More than two hundred thousand kinds of these plants are known. They vary enormously in size from that of certain water plants, the duckweeds, some of which are no larger than small pinheads, to the giant stature of the big trees of the Pacific slopes. The plants of this group vary greatly in habits of growth. Certain desert plants, for example, grow, produce flowers and seeds, and return to a dormant state following a favorable rain, while trees such as the sequoias may grow continuously for thousands of years. The flowers show a remarkable range in size, color, and odor, from those which are microscopic and without color or odor to others which are more than a foot long, are brilliantly colored, and have odors that may be carried long distances.

Monocotyledons and dicotyledons. *The flowering plants (angiosperms) are divided into two groups, monocotyledons and dicotyledons. In Chapter VII differences in monocot and dicot stems were discussed. The differences in seeds, flowers, and leaves are more easily observed than are the differences in stems, and serve as a ready means of distinguishing the two groups.

A monocot has only one seed leaf, or cotyledon. A dicot has two. A cotyledon, or seed leaf, is a small leaf-like structure of the young plant within the seed. The cotyledons supply the young plants with food until the plants develop sufficiently to make enough food to supply their own needs. The meaning of the terms *monocot* and *dicot* will be clear from a study of the two types of seeds.

Experiment 29. What is the structure of a typical dicot seed? Soak Lima beans or kidney beans overnight. How do the soaked beans compare in size with dry ones? On one side find the scar (hilum) where the seed was attached to the pod. Near one end of this scar is a small opening (micropyle). This opening permitted the entrance of the pollen tube when the egg which produced the seed was fertilized. It also serves



Some typical leaf forms. Which are monocots and which are dicots? How can you tell?

to admit water. Now remove the seed coat (testa). Note the two halves into which the bean separates readily. These are the cotyledons. Because there are two of them, the bean is called a dicotyledon, or dicot. Break the cotyledons apart carefully. Near one end you will find two small leaves (the plumule), and a rod-like structure (the hypocotyl). The cotyledons in the bean seed not only store food, but also digest it as the seed starts to grow. The cotyledons, together with the small leaves (plumule) and the rod-like structure (hypocotyl), form the embryo, or undeveloped plant. Make a sketch which will show the parts of the bean seed. Label your diagram in accordance with the figure.

Experiment 30. What is the structure of a typical monocot seed? Soak corn grains overnight or longer. As you examine a grain, do you note a light-colored region on one side? This is the embryo. Cut a grain in two lengthwise through the embryo region and stain one half lightly with iodine. The part which colors most deeply is the stored food (endosperm), which the embryo plant uses in its earliest growth. The rest of the inside of the grain is the embryo. You will find that the corn embryo has parts which correspond to those of the bean. The single cotyledon lies against the stored-food region. Because it has only one cotyledon in its seed, the corn is called a monocotyledon, or monocot. The cotyledon in the corn grain serves to digest the stored food and to transfer it to the growing region. Make a sketch of the corn grain cut lengthwise.

Not only can one find differences in the flowers, but also it is usually easy to distinguish the monocots from the dicots by the general forms of their leaves. The leaves of such monocots as corn, oats, lily, Easter lily, banana, and Solomon's-seal may be compared with the leaves of such dicots as cottonwood, bean, oak, elm, hickory, and geranium. The leaves of monocots have veins running somewhat parallel both with the large middle vein (midrib) and with one another. Very small veins connect the larger parallel veins. The leaves of dicots have a few large veins branching from the middle vein. Also, they have many smaller veins branching through the leaf. Such leaves are called net-veined leaves. Monocot leaves usually have smooth margins. Dicot leaves may have margins which are toothed or lobed[1]; or they may be compound, that is, made up of several similar parts. Monocot leaves usually have clasping leaf bases; that is, they are attached directly to the plant stems. In contrast, most dicot leaves have petioles.

Summary of differences between monocots and dicots. *Chapter VII and this chapter state points of difference between members of these two groups of flowering plants. A summary of these principal differences will be found convenient for reference.

Monocotyledons	**Dicotyledons**
Seeds	
One seed leaf (cotyledon)	Two seed leaves (cotyledons)
Stems	
Vascular bundles scattered through the stem; not arranged in a single ring.	Vascular bundles arranged in a cylinder surrounding the pith. The cylinder is not complete in a young plant.
Leaves	
Generally parallel-veined; generally smooth margins; generally clasping bases.	Generally net-veined; frequently toothed, lobed, or compound; generally possess petioles.
Flowers	
Flower parts—stamens, pistils, and petals—usually three, six, or nine in number.	Flower parts—stamens, pistils, and petals—usually in groups of four or five.

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[1] *Lobe* (lōb): a rounded, projecting part or division of such a plant organ as a leaf or fruit, or a projecting part of an animal organ, which is not entirely separated from the rest.

Some important monocots. The monocotyledons include such important families as the grass family, the palm family, the lily family, the orchid family, and many others. The grass family contains all our important grains, such as wheat, oats, barley, and corn, as well as sugar cane and bamboo. Some members of the lily family are tulip, lily of the valley, hyacinth, narcissus, onion, and leek.

Some important dicots. There are many more families of dicotyledons than there are of monocotyledons. Some of the more important families are given here. The rose family includes many plants such as cherry, apple, peach, pear, strawberry, raspberry, and rose, which vary greatly in growth habits. The members of the legume family include pea, bean, clover, alfalfa, peanut, locust tree, and redbud tree. Legumes can be recognized by their irregular flowers, which resemble the sweet pea, and by their pods, which contain the seeds. Legumes are important both because they produce food crops which are widely used by man and by his domestic animals, and because they make more fertile the soil in which they grow. How legumes make the soil fertile will be explained in a later chapter.

Some other large families, of which you may know one or more representatives, are the mint family, the buttercup family, the parsnip family, and the mustard family. The largest family of the dicotyledons is the composite family (Compositae), of which dandelions, asters, sunflowers, dahlias, and artichokes are examples.

Experiment 31. How are the structures arranged in a composite flower? Examine with a hand lens a composite flower, such as a dandelion, sunflower, aster, or dahlia. Does it have more than one pistil? Notice how easily the entire flower will separate into smaller parts. Are these all alike? Look at one closely. Can you find the stamens? How many petals are there?

The flowers of the composites are usually small, but are grouped into a head, or cluster, which we commonly call a flower. Thus a dandelion "flower" is really a collection of small flowers.

Self-test. 1. *Some* plants of this phylum (Spermatophyta) produce seeds.

2. The *monocot* plants usually have leaves with branching veins.

3. The leaves of monocots *usually* have petioles.

4. The grain plants are *dicots.*

5. Fruit trees, such as the peach and plum, are *dicots.*

6. The family of flowering plants whose flowers are grouped together in one head are the --?--.

Self-test on Important Biological Terms

algae
bacteria
dicot
fermentation
fungi
monocot
spore

Self-test on Biological Principles. Can you state facts from this chapter to prove this principle: "The more complex the structure of the plant, the greater is the division of labor in the plant"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why is water from deep wells likely to be practically free from bacteria, while that from the surface is likely to contain great numbers?

2. How can one keep molds from attacking foods and stored goods? Why does covering jelly with paraffin prevent molding?

3. Where are bracket fungi found? What are their characteristics?

4. Name from each phylum a plant of economic importance. Justify your selection.

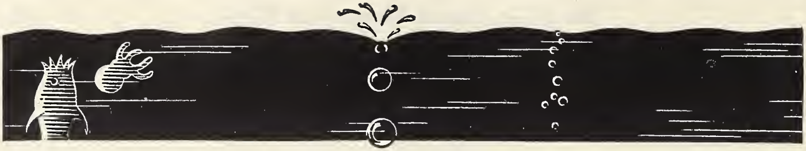
Project 6. To identify cone-bearing trees. Secure a tree guide and identify the cone-bearing trees (conifers) of your locality. Collect, from as many as possible of these, some cones that have not yet opened. When they are dry, the scales will open and expose the seeds. Make a record of the different kinds that you identify, stating where each grows.

Project 7. To identify monocots and dicots. Soak various kinds of seeds, such as peanut, sunflower, radish, pea, oats, and wheat. Examine them as you did the beans and corn. Classify the seeds as monocotyledons or dicotyledons. Make a record of those that belong in each group.

Project 8. To study the characteristics of young cone-bearing trees. Plant some of the seeds from a pine cone. Watch the plants closely as they come through the ground. How many cotyledons are there? Explain why the cone-bearing trees might be called polycotyledons. (See dictionary.)

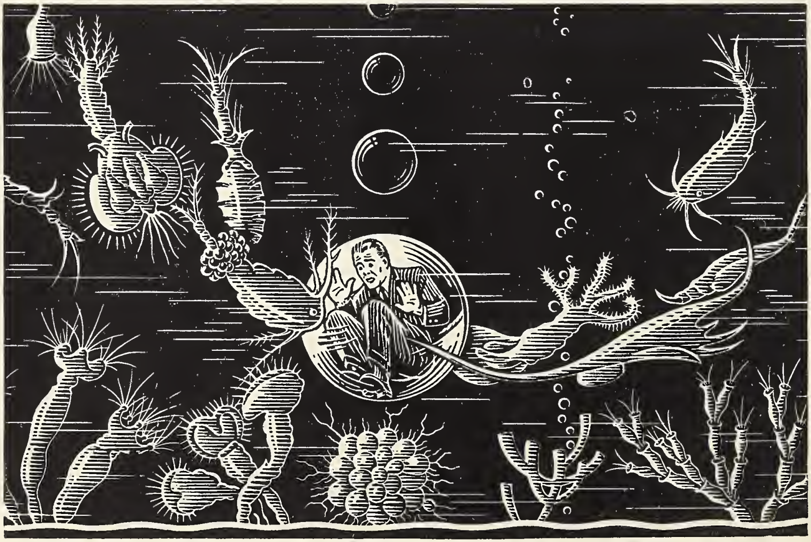
Project 9. To find twenty or more monocots and twenty or more dicots which have not been mentioned in this chapter. Use the summary given on page 145 to distinguish monocots and dicots. Keep a record of your plants, naming each if you can find its name. State for each plant the characteristics which led you to classify it as either a monocot or a dicot.

Project 10. To identify twenty or more common wild flowers. Use a flower guide to learn to recognize members of our commonest families of flowers. Keep a record of those you identify.



IF, RETAINING *sense and sight, we could shrink into living atoms and plunge under water, of what a world of wonders should we then form part! We should find this fairy kingdom peopled with the strangest creatures: creatures that swim with their hair, and have ruby eyes blazing deep in their necks, with telescopic limbs that now are withdrawn wholly within their bodies and now stretched out to many times their own length. Here are some riding at anchor, moored by delicate threads spun out from their toes, and there are others flashing by in glass armour, bristling with sharp spikes or ornamented with bosses and flowing curves; while, fastened to a green stem, is an animal convolvulus that by some invisible power draws a never-ceasing stream of victims into its gaping cup, and tears them to death with hooked jaws deep down within its body.*

HUDSON and GOSSE, *The Rotifera* (1886)



CHAPTER X

The Simpler Animals[1]

Questions This Chapter Answers. 1. What are some characteristics of the Protozoa? · 2. How do sponges illustrate complete metamorphosis in their life histories? · 3. How do sponges illustrate simple division of labor? · 4. What are some characteristics of *Hydra* and its relatives? · 5. What are some of the characteristics of flatworms? · 6. What is the life history of the tapeworm? · 7. What are some of the characteristics of roundworms? · 8. Why is the hookworm important? · 9. What is the life history of the parasite which causes trichinosis? · 10. What are some characteristics of the starfish and its relatives? · 11. What are some important facts about earthworms? · 12. What are some of the characteristics of the clam and its relatives? · 13. How does each of the phyla discussed in this chapter represent a higher stage of development than the preceding one? · 14. Of what importance are these various groups of animals?

WHAT ARE SOME ADAPTATIONS OF THE SIMPLEST ANIMALS[2] WHICH ENABLE THEM TO LIVE SUCCESSFULLY?

Protozoa. There are countless animals which live about us all our lives, but we are likely to remain unaware that some of them exist because they are too small to be seen with our naked eyes. With a microscope, however, we can invade their world and find out what they are like and how they live.

Experiment 32. What are the characteristics of some Protozoa? Put into a jar of water a little well-rotted barnyard manure, together with a handful of dry grass. Into another jar of water put some hay or some pond-weeds with some ooze from the bottom of the pond. After the jars have been left four or five days in a warm place, the water in each will have a foul-smelling scum at the top. Put on a slide a drop of water from the surface of one of the jars and examine it under first the low-power and then the high-power objective of the microscope. Do you observe any animals moving about in the drop of water? Prepare another slide with a drop of water from the surface of the second jar. Are the animals which you observe in the second drop like those in the first? Make other slides from each jar. A few threads of cotton put under the cover glass will hinder the movements of the animals and will thus give you a better opportunity to observe them. How many different kinds of animals can you learn to recognize in the drops? Can you discover how they move about? how they eat? how they get past objects in their way? Summarize your findings in one paragraph.

This experiment affords practice in making inferences. Can you explain how the Protozoa got into your culture?

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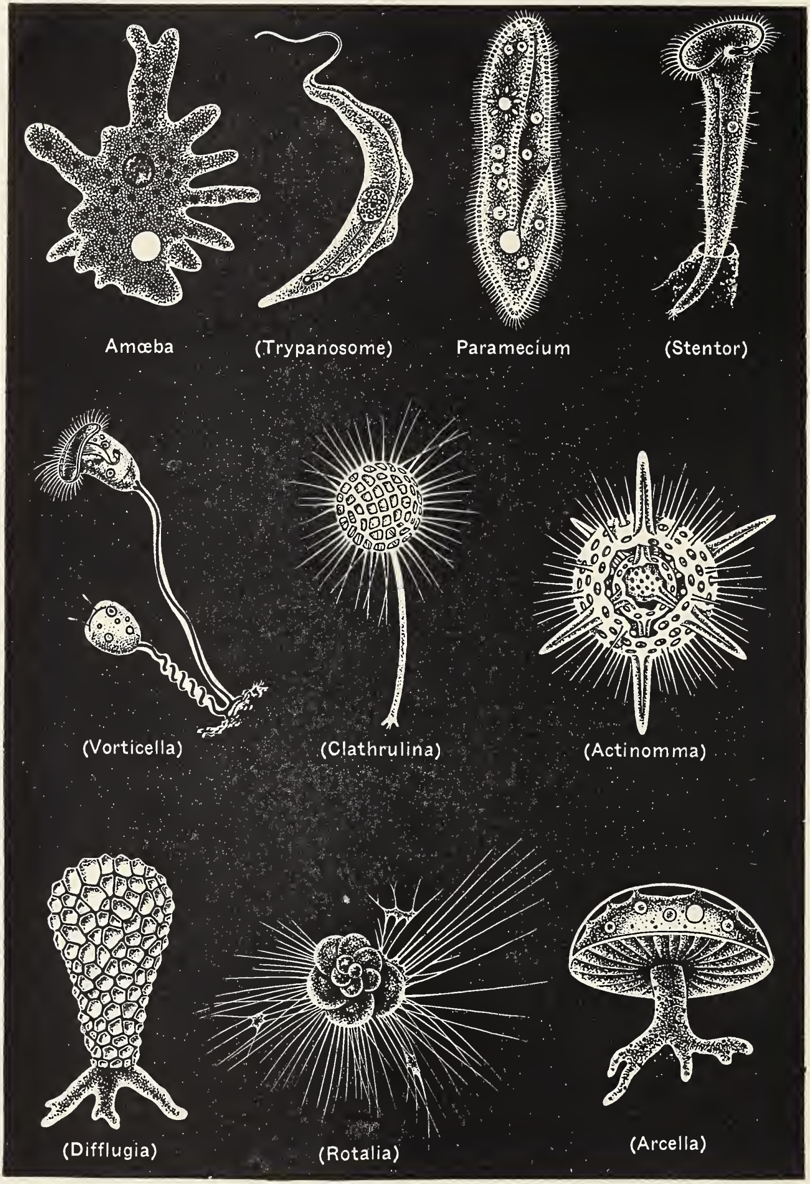
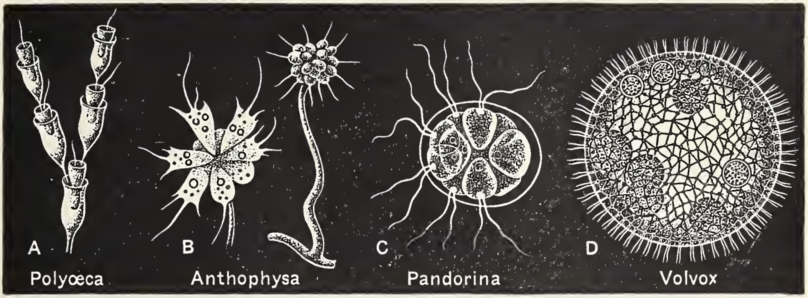
[1] To THE TEACHER. Not all the phyla of simpler animals are discussed in this chapter. Certain phyla are omitted because the animals composing them are relatively few and unimportant and are familiar chiefly to zoologists.

[2] Phylum Protozoa.



Protozoa. How are these Protozoa alike? The first five have no skeletons. The last five have skeletons of lime or silicon, or are protected by minute shells cemented together



Colonial Protozoa. Which of these colonies of Protozoa show tendencies toward division of labor? Can you find a volvox in the figure on page 127?

*Most of the organisms which you observed in this experiment were Protozoa.[1] The Protozoa are the lowest invertebrates[2] and also the simplest animals. They are to be found in almost every moist place. There are at least eighteen thousand different species known. Some live in fresh water, others in the ocean, some in damp earth, and still others as parasites in the bodies of many animals.

Although the body of a protozoan consists of only one cell, the animal performs all the life processes which every other animal must perform. It eats, digests its food, and attains its growth. It responds to stimuli,[3] such as light, heat, and vibrations in the water. It breathes, and it reproduces. Moreover, some forms of the Protozoa are even able to fight their enemies by sending out numerous thread-like darts.

Many of the Protozoa are able to survive even when the water in which they have been living has entirely evaporated. They form about their bodies protective coverings, called cysts. The protoplasm within the cyst remains alive but inactive. When the animal again becomes moist, it absorbs water and resumes active life.

Paramecium. Among the Protozoa you studied in Experiment 32 were probably some of the genus *Paramecium*. Paramecia are shaped somewhat like a slipper. A few species are large enough to be seen with the naked eye as white specks that move about very rapidly.

The animal moves by the action of hair-like projections[4] called cilia. These are located all over the animal's body. They beat back and forth, like hundreds of tiny oars, and cause the animal to move in a spiral direction either forward or backward. There will be many references to *Paramecium* and other Protozoa in later chapters of this book.

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[1] Singular *protozoon* (prō tō zō′ŏn) or *protozoan* (prō tō zō′ȧn).

[2] *Invertebrate* (ĭn vûr′tē brāt): the general name given to all animals which do not have backbones. *Vertebrates* (vûr′tē brāts): the higher animals, all of which have backbones.

[3] *Stimulus* (stĭm′ū lŭs), plural *stimuli* (stĭm′ū lī): any influence outside a living animal or plant which causes a movement or other response from the animal or plant.

[4] *Projection* (prō jĕk′shŭn): something that extends out from a surface.

Amoeba. In Experiment 32, if you were very fortunate, you may have seen an amoeba. This animal looks like a piece of bluish-gray jelly moving slowly through the water. It represents the simplest sort of animal life known. It is not a free-swimming animal like *Paramecium.* It moves about by crawling over the bottom in a peculiar way. As you watch one, you see it changing shape constantly. First there is a bulge on one side of the jelly-like mass. This bulge extends forward, and the rest of the animal then flows into the projection. Thus a projection forms on any portion of the animal, and the animal moves about by flowing into one projection after another.

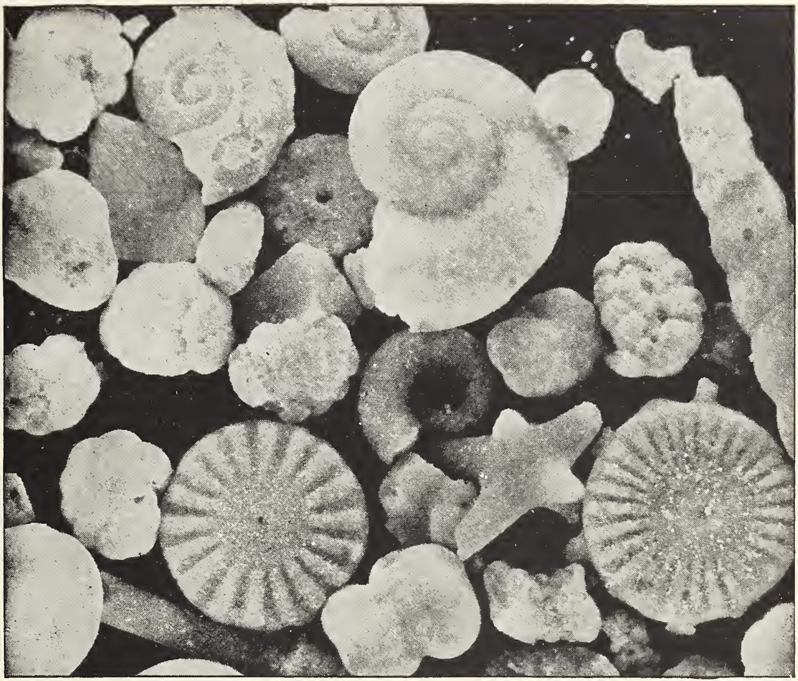
Other Protozoa. Several rather common Protozoa look more like flowers than animals. Such a protozoan is attached to a support by a stalk that either can be lengthened as the animal waves about in search of food or can be quickly contracted (see *Vorticella,* p. 150).

There are some animals of this phylum which do not seem to fit the definition of Protozoa. These forms live in groups, or colonies, and are therefore known as colonial forms. Usually the members of the colony are independent, each getting its own food and performing all other necessary functions.

Some of the stalked forms (such as *Polyoeca*) look like widely branched trees, each microscopic branch of which is made up of separate animals. Others (such as *Anthophysa*) look like a flower on a stalk, but each part of the head of the "flower" is a separate protozoan. Still other Protozoa (for example, *Pandorina*) form colonies which take the shape of a sphere. In them the separate animals are held in place by a jelly-like substance.

A large colonial form (*Volvox*) consists of many one-celled individuals which live together almost as if they were part of a many-celled animal. Threads of protoplasm connect one animal with another. The members of this colony are not entirely independent, as are the Protozoa which have already been described. Moreover, the member cells which make up the colony are not all alike. Only certain ones of these cells are able to reproduce. Those that can reproduce cannot capture their own food or help in moving the colony about. They share by osmosis the food secured by neighboring cells which cannot reproduce. The animals of this colony, therefore, show the first indications of division of labor, though not true division of labor, as will be seen later.

Like most of the one-celled plants, most of the one-celled animals have no skeletons of any sort. One large group, however, have shells of lime and



Buchsbaum

Photomicrograph (a photograph taken through a microscope) of Indiana limestone, showing that this rock is composed of the shells of ancient sea animals. Some of these were Protozoa. **Exercise on Scientific Method (Making Hypotheses):** Where do you think the materials out of which similar rocks may later be formed are being deposited today?

other minerals. When such animals die, these shells drop to the bottoms of the lakes or seas. In the course of time they become pressed together to form hard layers. In this way certain kinds of common limestone have been formed. The chalk cliffs of Dover, England, were formed in this way ages ago. The warping and folding of the earth's surface, finally, after millions of years, forced these layers above sea level.

Economic importance. *The Protozoa are important to man in several ways. Many of them serve as food for young fish. Certain other Protozoa, living as parasites in man and other animals, cause serious diseases, such as malaria and amoebic dysentery.

Further discussions of the Protozoa will be found in later chapters of this book.

Self-test. 1. *Few* Protozoa can continue active life if they become dry.

2. The Protozoa in a colonial form are *dependent on* one another.

3. Indications of division of labor are noted in the --?--.

4. Certain diseases are caused by Protozoa which live in the body as *saprophytes.*

5. *Fish* serve directly or indirectly as food for *Protozoa.*

6. Protozoa have existed on the earth probably for --?-- of years.

7. *Water* is necessary to the existence of *few* Protozoa.

WHAT ARE SOME ADAPTATIONS OF THE SIMPLEST MANY-CELLED ANIMALS, THE SPONGES,[1] WHICH MAKE THEM SUCCESSFUL ANIMALS?

Sponges. While fishing or swimming in a stream or pond, you may have seen fresh-water sponges. They form patches of gray or green, attached to stones or sticks in protected places. These patches are usually less than an inch thick but often cover several square inches. They have the appearance of being plant life. The green color of some of them suggests chlorophyll, making them seem all the more like plants. When the masses are examined closely, however, the green color is usually found to be due to algae on the surface of the sponge.

*The sponges are the lowest Metazoa, that is, animals having bodies composed of many cells. They mark the next step in the scale of life above the Protozoa.

Fresh-water sponges are found in rivers, lakes, and canals in all parts of the world. Marine, or ocean, sponges are found in all the seas and at all depths, from the shallow water along the shore to the deepest abysses. Sponges vary widely in form and in size. They may be as small as a pinhead or almost as tall as a man. While most sponges are white or gray, some marine species are colored with the hues of the rainbow.

Structure of sponges. Sponges are relatively simple in structure. The body, which is generally tube-like, consists of two distinct layers of cells. The outer layer is of relatively large cells, which form a covering for the rest of the body. The inner layer is very similar to the outer one and forms a covering for the inside of the body. Between these layers is a jelly-like region. Scattered through this are wandering amoeba-like cells.

Water enters through numerous openings, or pores, in the body wall of the sponge and passes out through a large opening at the end. A continuous current of water is created by the movement of whip-like structures (flagella)

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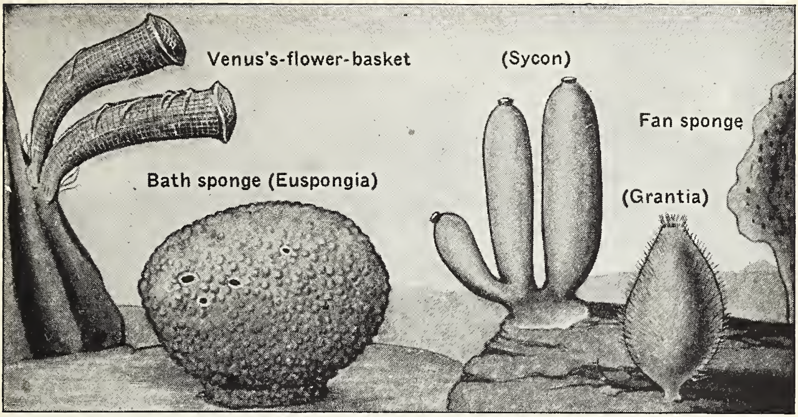
[1] Phylum Porifera.



Marine sponges. Not all the sponges shown here live in the same part of the ocean or at the same depth. There are at least twenty-five hundred species of sponges. What is meant by the statement "The sponge is a successful animal"?

which project from the cells lining the inner cavity. This stream of water brings to the animal oxygen and food. The food consists of microscopic plants and animals and other organic particles.

Sponges have skeletons of a tough material (spongin) like silk or of a substance like glass, forming a network all through the body. In the sponges, as in many other of the simpler animals, the skeleton serves chiefly to protect the soft parts of the body from enemies.

A large bath sponge has the same general structure as the simple sponge just described. It is really made up of a number of separate sponges, which have developed as buds or branches of an older parent sponge.

Division of labor. With some of the colonial forms of the Protozoa, as has been explained, different kinds of cells carry on certain functions, such as food-getting or reproduction. Each profits to some extent from the activities of the others; yet the food-getting cells *could* live independently, that is, without help from other cells.

The sponge, however, represents a higher stage of animal development than the colonial Protozoa. Not only is it more complex in structure, but also, because of this increased complexity,[1] it shows a true division of labor. Thus the cells along the inner cavity of the sponge do the work of food-getting and digestion for all the cells. Other cells of the inner layer secrete the material that forms the skeleton. Those on the outside serve as a protective covering for the inner cells. Each layer of cells has its special functions.

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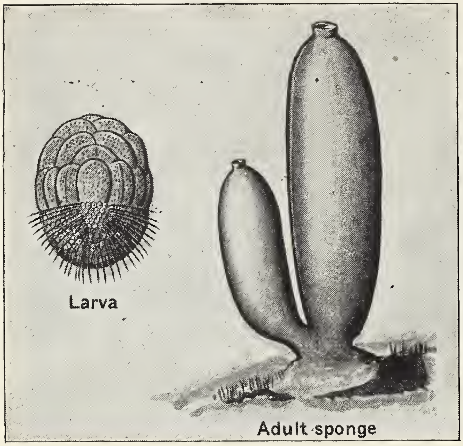
[1] *Complexity* (kŏm plĕx'ĭ tĭ): state of being complex, that is, the opposite of simple. *Complicated* (kŏm'plĭ kāt ĕd): complex, or the opposite of simple.



Sponge larva and adult sponge. Explain how these drawings illustrate the complete metamorphosis of the sponge. The larva is actually very small as compared with the adult

No single sponge cell could live independently, nor could the cells in one layer live without the help of the cells either in the other layer or in the jelly-like region. Yet a small group of sponge cells which includes some cells from each of the layers can live independently. Thus small pieces which are cut from a sponge can grow to form a large sponge. The sponge, therefore, illustrates in the simplest way the biological principle that every cell of a many-celled animal (metazoan) takes part in the division of labor; that is, every cell has certain work to do for the survival of the whole animal.

Metamorphosis.[1] The adult[2] sponge is always attached to a stone, a stick, or some other object. The young sponges, or larvae, however, swim freely. They do not resemble the adult sponges. When an animal goes through two or more stages in developing from the young to the adult form, the animal is said to undergo a metamorphosis. If the change from one stage to the next is abrupt, and if the animal in each stage appears to be entirely different from the same animal in the preceding stage, the metamorphosis is said to be a *complete metamorphosis.* The sponge is the simplest animal having a complete metamorphosis in its life history. Many examples of complete metamorphoses of more complex animals will be found in later sections of this book.

Importance of sponges. Few animals use sponges as food; but many animals, such as worms, insect larvae, and crustaceans, may seek shelter in the pores and hollow bodies of sponges. None of the fresh-water species is of

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[1] *Metamorphosis* (mĕt ă môr′fō sĭs): the changes in form and appearance which certain animals undergo in developing from the egg to the adult. Plural *metamorphoses* (mĕt ă môr′fō sēz).

[2] *Adult* (ă dŭlt′): a mature specimen.

Galloway

Cleaning sponges that have just been gathered. **Special Report:** Describe sponge fishing and the preparation of sponges for market. (Consult a college textbook of zoology or an encyclopedia)

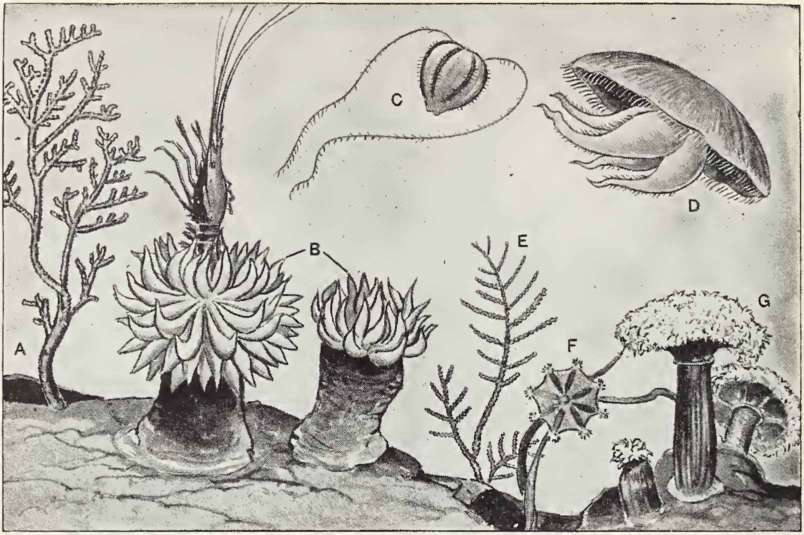
value to man. The skeletons of several species of marine sponges, however, are used as bath sponges, for the padding of coats, and for a variety of other purposes in industry and in the home. The best bath sponges are secured from Florida, Cuba, the Mediterranean coast, Australia, and the Bahamas.

Self-test. 1. Sponges (1) are plants; (2) live only in the ocean; (3) live both on land and in the water; (4) live both in fresh water and in the ocean; (5) live only in fresh water.

2. The simplest of the Metazoa are *Protozoa,* having bodies made up of many cells.

3. The body of the sponge is made up of *three* layers of cells.

4. In developing from the larva into the adult sponge the animal undergoes a *complete metamorphosis.*



A group of marine coelenterates.[1] A, a coral-like form (*Gorgonia*); B, two sea dahlias (*Tealia*), one capturing a prawn; C, a sea gooseberry (*Pleurobrachia*); D, a jellyfish (*Aurelia*); E, a coral-like form (*Sertularia*); F, a jellyfish (*Haliclystus*); G, sea anemones (*Metridium*). From a study of the text, in what respects should you expect all these coelenterates to be similar? There are about forty-two hundred species of coelenterates

5. *Few* of the individual cells of the sponge could live alone.

6. The simplest animal in which there is true division of labor is (1) *Volvox*; (2) a sponge; (3) *Paramecium*; (4) *Pandorina*; (5) *Amoeba*; (6) a liverwort.

7. The only part of the sponge which is useful in industry is its --?--.

WHAT ARE SOME ADAPTATIONS OF HYDRA AND ITS RELATIVES[2] WHICH MAKE THEM SUCCESSFUL ANIMALS?

Animals that look like plants. The corals, sea anemones, jellyfish, and fresh-water hydras all belong to the group of coelenterates. All these animals are found in the water, most of them in the ocean. They are often beautifully colored and vary greatly in form. With the exception of the jellyfish and a few related kinds, they grow attached to rocky bottoms or to some other support. They occur in such great abundance that they cause the ocean floor of the warmer seas to look like a garden of many-colored plants. Their branching habit gives them the appearance of plants. It is not strange, therefore, that they were first classified as plants by earlier scientists who studied them.

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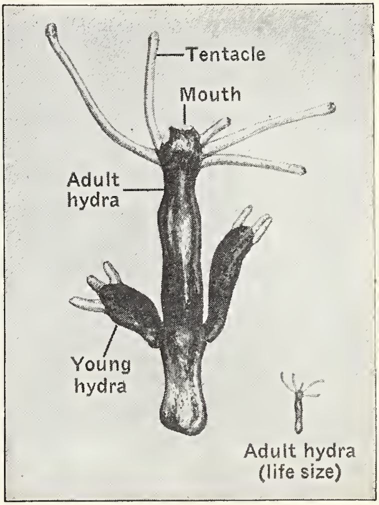
[1] *Coelenterate* (sē lĕn′tĕr āt). See the Glossary for *Coelenterata*.

[2] Phylum Coelenterata.

Characteristics of coelenterates. *These animals have bodies that are essentially two-layered bags. They have no right and left sides, but are made up of like parts arranged around a common center. Thus, if they were divided in two from top to bottom along any diameter (for example, as one would cut across a pie), each half would be like the other.[1]

At one end of the tube-like body is the mouth. It serves both to take in food and to give off wastes. Around the mouth is a circle of long projections called tentacles. The tentacles and much of the rest of the body are covered with stinging cells. These capture food and provide defense against enemies. The tentacles convey the food to the mouth.

The animals in this phylum mark a higher stage of development than the sponges, in having (1) a single opening into the body and (2) a central cavity in which digestion takes place.



The hydra. Hydras may be found in almost any fresh-water pond or stream. Is *Hydra* a parasite? Justify your answer

Hydra. People who live far away from the ocean have little opportunity to observe jellyfish and sea anemones alive. But we can study a very common little coelenterate found in nearly all our small lakes and streams. It is *Hydra*, an interesting animal less than half an inch long, either green or brown in color. It is usually found attached to the leaves or stems of water plants.

If a hydra is removed from the water, it shrinks into a shapeless mass of protoplasm. When returned to the water, it resumes its usual appearance. From this behavior we infer that the body is not supported by a skeleton of any sort, but that it depends on the water to hold it up. The body is indeed a cylinder-shaped bag, with one end attached to some solid object and with a mouth surrounded by tentacles (usually six in number) at the other end.

Most of the time *Hydra* remains attached. Its only movements then are a stretching and a contracting of its body and a waving of its tentacles. But

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[1] Animals so constructed are said to be *radially symmetrical.*

VACATION-TIME BIOLOGY

Of the many new animals we saw on our first visit to the ocean, none held us more entranced than the jellyfish. The ocean that first evening seemed fairly alive with them. They gave off flashes of light here and there, streaks of color in the wake of a passing boat, or a steady glow where they had collected about a log that was drifting offshore. We couldn't leave such beauty even for the night. So we dipped out a few of the fascinating animals and carried them home.

For an aquarium we used an old washtub in which the jellyfish, which were three or four inches across, swam about with a movement somewhat like the opening and closing of an umbrella. For several days we enjoyed them. Then one morning we found them floating on the surface, almost dead. The water was cloudy, too, as if they had already begun to decompose. We had about decided to empty the tub when someone who had dipped out some of the water in a glass noticed specks moving about. Could they be young jellyfish? We looked again at the old jellyfish. The egg sacs, which had been the most conspicuous parts of their bodies, were now small and wrinkled. That was evidence enough. The eggs had been laid in the water and had hatched overnight into thousands of little jellyfish. We filled other glasses with the cloudy water.

After breakfast we returned for another look at the little jellyfish. But something had happened! The water was no longer cloudy. Where were those thousands of little jellyfish? We held a glass up to the light and looked closely. There they were, small, transparent lumps of jelly fastened to the glass. With a magnifying glass we could see that they were alive. Now came another surprise. By the next morning those small lumps of jelly had developed arms, four of them, stretching out from the top. The little animals looked much more like flowers than like jellyfish. Apparently young jellyfish do not resemble their parents. Father said we should now call them hydroids. In a week they had grown to be a quarter of an inch long, and many of them had more than four arms. We could now see plainly that the arms had work to do. They reached out and swept particles of food into the mouth, which was in the center of the circles of arms. But that was all our hydroids did for weeks—just eat and grow.

Then one spring morning our next surprise came. The hydroids stopped eating, a fact that made us suspect that something new was about to happen. We examined them closely. Each, now about half an inch long, looked as if pieces of string had been tied tightly about it in six or eight places. The furrows thus made became deeper and deeper, until each hydroid looked like a pile of very shallow cups. The arms became shorter, then disappeared.

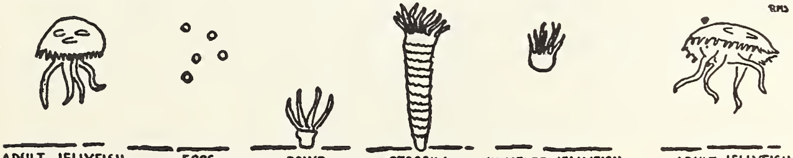
Soon the upper cup started moving, jerking back and forth and up and down.

Livingstone

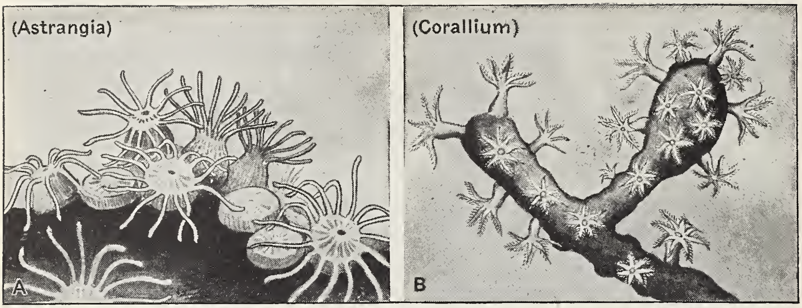
The shore where were found many interesting specimens for a biology museum

Finally it broke loose from the rest, turned itself over, and swam away. It was a jellyfish, very small but otherwise like the first ones we had found. One by one the rest of the cups followed the example of the first, until the water contained hundreds of little jellyfish swimming about. Father said they would grow to be adult jellyfish. These would lay eggs which would again develop not into jellyfish but into hydroids. Thus hydroids would produce jellyfish, and jellyfish would produce hydroids.

We had observed the "alternation of generations" in the jellyfish hydroid family. Later we learned of many other organisms which have alternation of generations in which, as Tom remarked, "the youngsters look exactly like their grandparents, but not at all like their parents."



A drawing copied from a vacation-time notebook. Can you explain how it shows alternation of generations?



Coral colonies. Of these two coral colonies, A is common along the north-Atlantic coast, and B is a valuable coral from tropic waters. How many relatives of the coral can you name?

it has several ways in which it can move slowly from place to place. One method somewhat resembles that of a measuring worm. It bends its body over until its tentacles touch a support; then it lets go with its "foot" and literally stands on its head. Then its "foot" is attached again, and its tentacles are straightened upward. A second method, which, however, it rarely uses, is to walk on its tentacles as if they were legs. Besides these methods of locomotion *Hydra* often slides along on its "foot," much as a snail does.

Division of labor in a coelenterate. The body of such a coelenterate as *Hydra* is made up of cells arranged in two layers. Yet simple as this animal is, it nevertheless possesses several kinds of highly specialized[1] cells. These make it a more complex animal than the sponge. The outer layer (ectoderm) serves chiefly for protection. It contains (1) muscle cells, which enable the animal to expand and contract and to move about; (2) stinging cells, which aid in securing food and repelling enemies; (3) nerve cells, which respond to light and other stimuli. In addition, certain of the cells may become modified to carry on reproduction. The cells of the inner layer (endoderm), like those of the sponge, digest food for the whole animal.

Corals. The individual coral animals (polyps) are very much like *Hydra*. They live in large colonies. These colonies, or coral masses, differ greatly in form. Some are slender and branching. Others are rounded and smooth.

Each animal builds around its tube-like body a skeleton of limestone, into which it can withdraw when necessary. Little by little a great mass of rock-like material is built up by the skeletons of succeeding generations of coral animals. In this way, over long periods of time, corals have added much land to the margins of continents.

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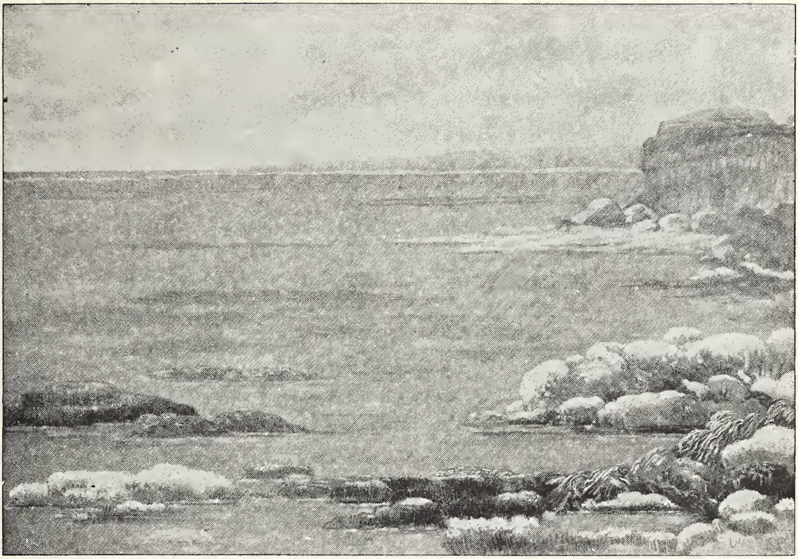
[1] *Specialize* (spĕsh'ăl īz): to prepare or set aside for some special purpose.



©F. M. N. H.

The site of Chicago about four hundred million years ago was a coral reef which probably looked somewhat like this picture. At that time the region was covered by an arm of the Arctic Ocean. **Exercise on Scientific Method (Making Inferences):** From the fact that corals grew in the water do you infer that the water was then cold or warm?

Economic importance. Except for their work in building coral reefs and islands, the coelenterates are of relatively little economic importance to man. The skeletons of some corals are used for jewelry. Jellyfish are eaten by fish and whales; but since their bodies are 99 per cent water, they do not furnish much real nourishment.

Self-test. 1. *All* of the corals and their relatives are free-swimming forms.

2. The coelenterates mark a higher stage of development than the sponges because (1) they have a two-layered body; (2) they look more like flowering plants; (3) they live chiefly in the ocean; (4) some of them have no skeletons; (5) they have a single mouth and a single digestive cavity.

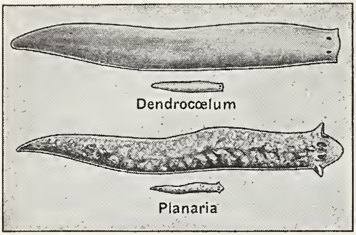
3. *Hydra* represents a *higher* degree of division of labor than the sponges because it has more different kinds of cells with different functions.

4. The coelenterates are of *great* economic importance.

5. *Hydras* live in great colonies.

WHAT ARE SOME ADAPTATIONS OF THE FLATWORMS[1] WHICH ENABLE THEM TO LIVE SUCCESSFULLY?

Wormlike animals are not always true worms. We are likely to call any long, crawling creature a worm. A careful study of these various "worms," however, shows that most of them are not truly worms at all. The caterpillars, cabbage worms, tomato worms, apple worms, and other "worms" of this type are not true worms. They are the larvae of certain insects and will later develop into moths, butterflies, or other insects. The centipedes, in spite of their wormlike appearance, are not even closely related to true worms. They are near relatives of the insects, crabs, and spiders. None of the true worms has legs to aid it in crawling, as the caterpillars and centipedes have.



Flatworms. The smaller drawings beneath the larger ones of these common flatworms show actual sizes of these animals. **Special Report:** How many species of flatworms are known? (Consult an advanced zoology textbook or an encyclopedia)

We are not likely to be familiar with many types of true worms, because many of them live in the sea, many others live in the ground, and still others live as parasites in the bodies of other animals and plants.

The true worms make up three phyla of the animal kingdom: (1) the flatworms (Platyhelminthes), such as tapeworms; (2) the roundworms (Nemathelminthes), such as hookworms and horse-hair snakes; (3) the segmented worms, or annelids (Annelida), such as earthworms. Of these true worms the annelids are much higher in the scale of life than the flatworms and the roundworms.

Characteristics of flatworms. Most flatworms have bodies which are soft, thin, and much flattened. They are fairly primitive[2] animals; yet they are definitely a higher type of animal than the coelenterates. Unlike both the coelenterates and the even simpler sponges, the bodies of which consist of only two layers of cells, the flatworms have bodies made up of three body layers. Thus the flatworm is the most primitive animal having the three-layer plan of body development which is common to all the higher animals. All flatworms, moreover, can always be divided into similar right and left halves.[3]

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[1] Phylum Platyhelminthes.

[2] *Primitive* (prĭm'ĭ tĭv): showing an earlier or a simpler stage of development.

[3] Animals so constructed are said to be *bilaterally symmetrical.*

This bodily arrangement is the same as that possessed by the higher animals. Among the flatworms, too, are the simplest crawling Metazoa.

Many flatworms have fairly well-developed reproductive,[1] excretory,[2] muscular, and nervous systems. This fact indicates a much higher degree of division of labor among the cells and tissues of the body than is found in the simpler animals already discussed.

Fresh-water flatworms can be found on the under-sides of stones or in the mud at the bottom of streams and ponds in almost any part of the earth. The life processes of one of these simple flatworms will be discussed in several later sections of this book.

Flatworms interest us chiefly because many of them live as parasites in the bodies of man and other animals. There is probably not a single group of higher animals that escapes being made a host by some of these worms. Several are intestinal[3] parasites in the dog, the pig, fish, man, sheep, and many other animals. Others may live in the muscles of the pig, the cow, and man. Still others may be found in such organs as the liver. Two of these forms, the tapeworm and the liver fluke, are of interest both because they are of economic importance and because they have such unusual and complex life histories.

Tapeworms. The tapeworms are among the best-known flatworms. Most of these parasites require two different hosts in order to survive. They go through a different stage of development in each host in turn. There are many species, which live as adults in the intestines of animals. Fifteen or more species are known to infest[4] man, but only four varieties are especially important as human parasites. These are the beef tapeworm, the pork tapeworm, the double-pored cat or dog tapeworm, and the broad fish tapeworm of man.

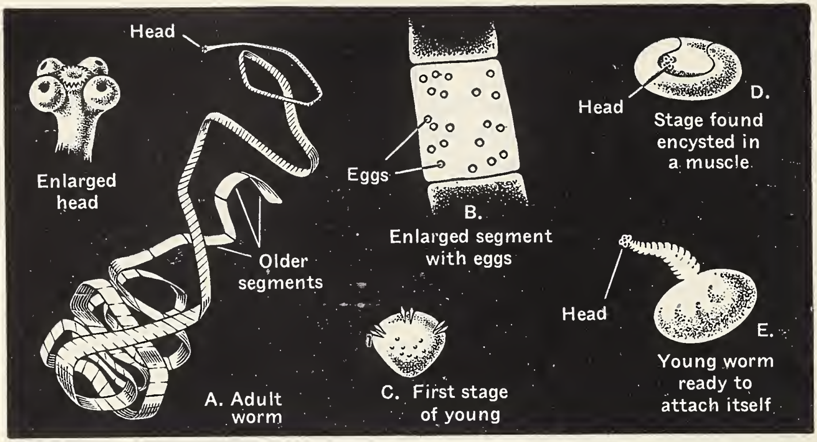
Tapeworms are made up of many similar parts. A single animal may consist of from three to several thousand sections, depending on the species. The adult form of the most familiar tapeworm is a ribbon-like worm. It is firmly attached by sucking disks or by hooks on its head to the wall of the small intestine of its host. The body floats free in the intestine. It is therefore surrounded on all sides by digested food, which it takes into every part through the body wall by osmosis. So dependent has the tapeworm become during its

[1] *Reproductive* (rē prō dŭk'tĭv): having to do with reproduction.

[2] *Excretory* (ĕx'krē tō rĭ): having to do with excretion. *Excrete* (ĕx krēt'): to eliminate waste materials from the cells. *Excretion* (ĕx krē'shŭn): the act of excreting or a substance excreted.

[3] *Intestinal* (ĭn tĕs'tĭ năl): having to do with the intestine. *Intestine* (ĭn tĕs'tĭn): the part of the food canal below the stomach.

[4] *Infest* (ĭn fĕst'): to be present in such large numbers as to be annoying or dangerous.


Head
Enlarged head
Older segments
A. Adult worm
Eggs
B. Enlarged segment with eggs
C. First stage of young
Head
D. Stage found encysted in a muscle
Head
E. Young worm ready to attach itself

Various stages in the life history of a tapeworm. What may one do to prevent becoming a host to this parasite (*Taenia saginata*)?

long process of adaptation that it has lost all traces of a digestive system of its own. Moreover, it depends on its host for shelter and warmth, as well as for food.

Life cycle of a tapeworm. The tapeworm undergoes a complete metamorphosis in developing from newly hatched young to the adult stage. The eggs are swallowed by one host, such as a cow, a pig, or a fish, along with food or water. As soon as it hatches from the egg, the young tapeworm (*C* in the figure) bores through the walls of the stomach or the intestine. It is then carried by the blood stream to the muscles of its host. Here it grows, develops a head, and soon forms a cyst (*D* in the figure). It can never develop into the adult stage in this first host. But if the meat containing the living young tapeworm (*D*) is eaten, the worm continues its development to the adult stage in the intestine of man. Here as an adult it may sometimes attain a length of more than thirty feet. It grows by adding new sections just behind the so-called head. This process keeps pushing the older, wider parts of the body farther and farther back.

Every section of a tapeworm contains both male and female reproductive organs. Enormous numbers of eggs are produced by these prolific[1] animals; indeed, nearly the entire space within each section is taken up by the egg masses. When the eggs are fully developed, the sections break off, usually in chains, and pass out of the body with the feces, or wastes from the food

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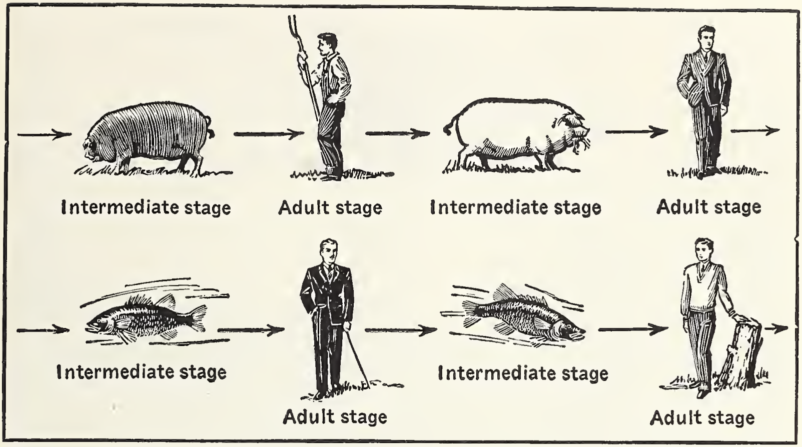
[1] *Prolific* (prō lĭf'ĭk): producing many young.



The alternate hosts in the life histories of two kinds of tapeworm. With the help of the text can you explain the metamorphosis of the tapeworm?

canal. If a suitable host happens later to swallow these eggs with its food, the life history is repeated in the same way. But if no suitable host comes along, the young tapeworms in the eggs soon die. By producing thousands of young, such parasites survive, even though there is so slight a chance that the eggs will be swallowed by a suitable host or that the partly developed young in the flesh of the first host will be eaten by a suitable second host in which the adult worm may develop.

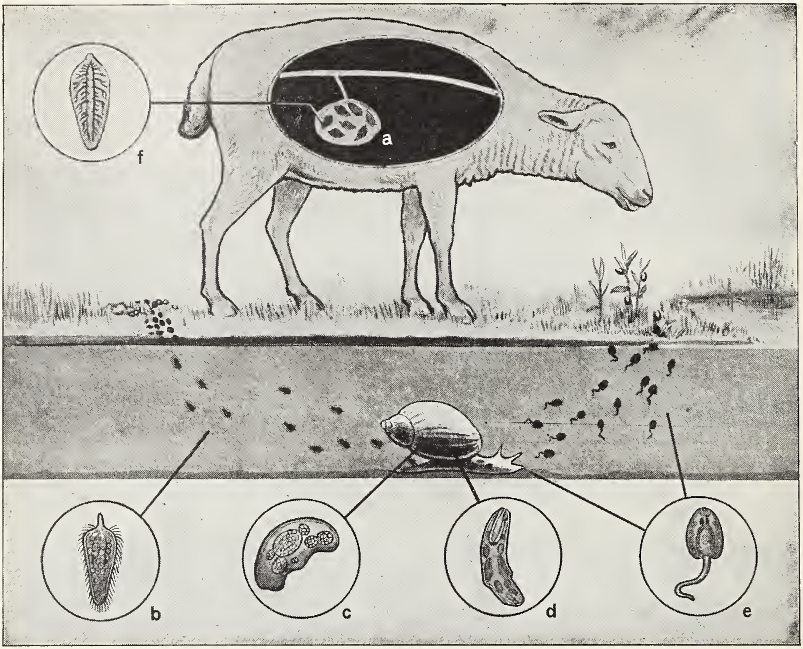
A tapeworm living in the intestine of man or of any other animal interferes with digestion and may absorb so much food that the health of the host becomes affected. Thorough cooking of meats prevents human beings from becoming infested with tapeworms.

Under certain conditions man serves as the host for the larva of the pig tapeworm. Sometimes the microscopic eggs or the newly hatched young of this parasite find their way into the mouth from dirty hands or unclean food. The young worms may then be carried by the blood to almost any part of the human body. Here they may cause more or less serious injury.

The eggs of several species of tapeworm, including the pig tapeworm, can be carried to man by houseflies which deposit the eggs on food.

Self-test. 1. The flatworm marks a higher stage of development than the sponges or the coelenterates because it has a *two*-layered body.

2. The three phyla which include the true worms are the __?__, __?__, and the __?__.



The life history of the liver fluke. Like the tapeworm, this parasite requires two hosts. These hosts are a sheep and a certain kind of water snail. **Special Report:** The life history of the liver fluke

3. The most important flatworms are *saprophytes.*

4. The tapeworm takes in its food by the process of *photosynthesis.*

5. One need never fear becoming the host of a tapeworm if the meat one eats is always *well cooked.*

6. A *flatworm* which sometimes infests sheep is the liver fluke.

WHAT ARE SOME ADAPTATIONS OF THE ROUNDWORMS[1] WHICH MAKE THEM SUCCESSFUL ANIMALS?

Characteristics of roundworms. Roundworms are more complex than flatworms. Hence they are somewhat more advanced in the scale of life than the flatworms. They have a food tube, or alimentary canal, which lies in a body cavity.

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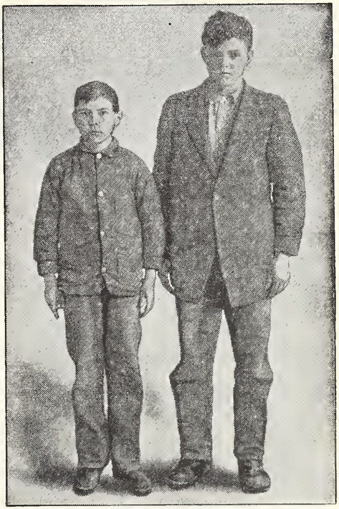
[1] Phylum Nemathelminthes.

Roundworms vary in size from microscopic forms to animals two feet long. Some species are marine, others live in fresh water, and still others live in moist soil. With the roundworms as with the flatworms, however, the most important species are parasites of plants and animals. Perhaps the most formidable of these are (1) the hookworm, (2) the parasite that causes trichinosis (*Trichinella*), and (3) a parasite of the intestines (*Ascaris*).

The hookworm. Hookworm disease is prevalent in most warm countries. It is caused by a thread-like worm not more than a quarter to half an inch long which may live in the intestine of man. Scientists working with the Rockefeller Foundation report that in certain countries nearly all the people have become infested with this parasite. In southern China 65 per cent of the population are affected. In India as many as 95 per cent have the disease. Also in some parts of the southern United States the disease is common.

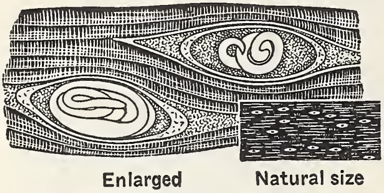


International Sanitary Commission

The boy at the left is infested with the hookworm parasite. The other boy is not. Both are eighteen years old. State several ways in which the study of biology aids in fighting this disease

*The larvae of this worm get into the bodies of human beings by boring through the skin, usually of the feet, since, in countries where the disease is prevalent, the people commonly go barefoot. The larvae are taken up by the blood stream at the point where they enter the skin. They are carried by the blood to the lungs, through which they bore. From the lungs the worms may pass up the windpipe to the throat. They are then swallowed and finally reach the intestine. The parasite attaches itself to the wall of the intestine and sucks the blood of its host. At the same time it pours into the wound a poison which keeps the blood from clotting. Therefore, even after the worm has left the spot, blood may continue to flow from the wound. The constant loss of blood weakens the host. The victim is also likely to contract tuberculosis because of injury to the lung tissue and because of weakness due to the loss of blood.

The eggs of the hookworm pass out of the body with the feces. They hatch into larvae in the moist earth, where they are ready to attack a new host. Among people who know these facts control is easy. If all human wastes are disposed of in such a way as to prevent pollution[1] of the soil, the disease can be stamped out readily. Sanitary toilets and the wearing of shoes are effective aids in eliminating the danger from hookworm.



A trichinosis parasite in human muscle. How may one guard against becoming infested with this dangerous parasite? About fifteen hundred species of roundworms are known

Social implications. The loss of human energy and even of human life from the hookworm parasite is appalling. Not only are those who suffer from this disease wretched, but also they are unable to work effectively and to provide satisfactorily for themselves or their dependents. This condition is a matter of grave concern to everybody. Every effort should be made to encourage scientists to discover more effective ways of preventing and eliminating hookworm disease. The best ways of preventing and curing this disease should be widely known and readily available to all sufferers.

Other roundworm parasites. Like many other parasitic worms, the trichinosis parasite must pass part of its life in each of two hosts. The first part of its life is passed in the pig. There it rests encysted in the muscles. If this meat is eaten by man before it has been thoroughly cooked, the digestive juices dissolve the cyst, and the worm is set free in the intestine. It reproduces there, depositing as many as ten thousand young. These find their way by means of the blood stream to the muscles. They bore through the tissues, causing them to swell and to become painfully inflamed. The muscles most liable to be infested are those which have a plentiful supply of blood, as the muscles of the thorax and diaphragm.

*The prevention of the disease lies in thoroughly cooking all pork. There is no government inspection of meat for the trichinosis parasite, since it is impossible to tell, merely by looking at meat, whether or not it is infested.

Some of the roundworm parasites (*Ascaris*) live in the lower intestines of children, dogs, pigs, and probably many other animals. Except that these enter through the mouth instead of through the skin, they have a life history similar to that of the hookworm. The worms injure their host in various ways: (1) they cause him to be nervous and restless; (2) they make it impossible for him to secure sufficient nourishment; and (3) they may so injure him that he cannot effectively resist attacks of germ diseases, especially pneumonia.

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[1] *Pollution* (pŏ lū'shŭn): the act of making dangerously unclean or state of being dangerously unclean.

Self-test. 1. Roundworms mark a higher stage of development than the flatworms because (1) they are parasites; (2) some species live in the ocean; (3) they have an alimentary canal in a body cavity; (4) the adults are always wormlike; (5) they are in general much smaller than flatworms.

2. One may become infested with the *hookworm* parasite by going barefoot.

3. Roundworms are parasites in *few* animals besides man.

4. Roundworms cause *small loss* of life.

5. Thoroughly cooking all pork removes all danger from the --?-- parasite.

WHY ARE THE ECHINODERMS[1] ABLE TO LIVE SUCCESSFULLY?

Spiny[2]-skinned animals. If you were to explore the pools about the rocks on the ocean beach at low tide, you might find several different kinds of echinoderms, or animals with spiny coverings. Among them you would be likely to discover a sea urchin. But unless you should happen to observe it moving slowly about, you probably would not recognize it as an animal at all, since it resembles a small black or purple cactus. Near the sea urchin on the rocks you might observe purple or orange starfish, having five, six, or more arms. On the beach you might find gray sand dollars which had been washed up by the tide. Most of these sand dollars would probably already have been broken by the waves or by sea gulls preying upon the animals inside the shells.

The sea urchin, the starfish, and the sand dollar are echinoderms, or spiny-skinned animals. They are given this name because all have exoskeletons made up of bony[3] and often spiny plates.

With almost no exception the echinoderms are all marine forms. They live mostly in tide water, that is, the shallow water along the ocean shore. Like the coelenterates, all echinoderms have bodies made up of like parts around a common center.[4] Most of the echinoderms have five arms, or rays. Occasional starfish, however, have six or seven; and some basket stars and serpent stars have several times as many. Most species of echinoderms can move about slowly. A few stalked forms are attached to rocks or other supports.

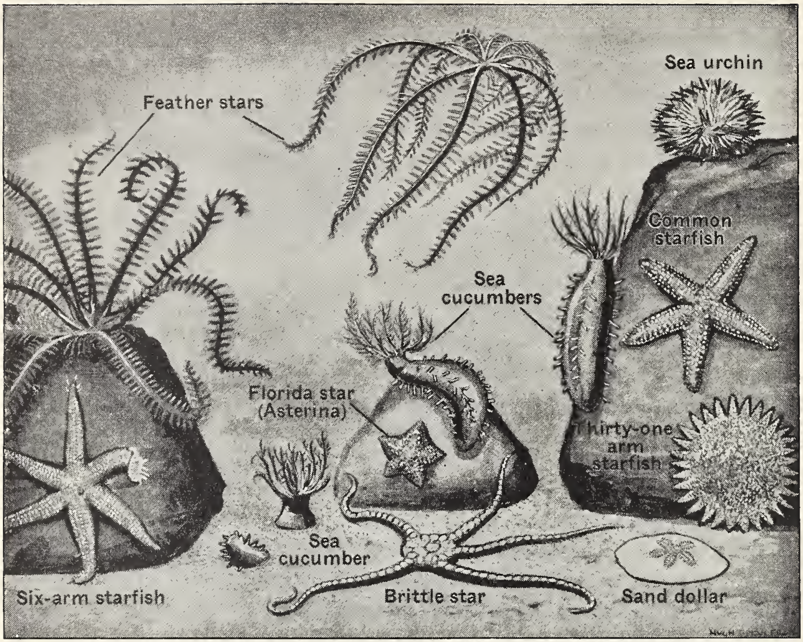
The starfish, a typical echinoderm. Starfish are found on the ocean shores in all parts of the world. The living animal is somewhat flexible. Like its

[1] Phylum Echinodermata.

[2] *Spiny* (spī′nĭ): covered with spines, or stiff, sharp-pointed structures.

[3] *Bony* (bō′nĭ): consisting of bones or like bones.

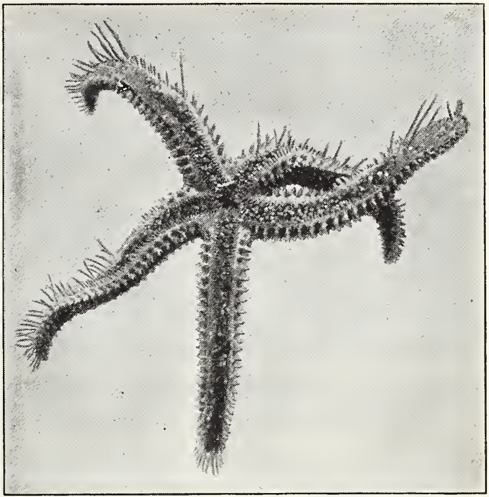
[4] See footnote, p. 159.



Echinoderms. The echinoderms are not here represented in their correct relative sizes. Also, one would not find so many kinds together in one place. There are about four thousand species of echinoderms. What is meant by the statement "Echinoderms are littoral animals"? (See dictionary)

near relatives, the sea urchins, brittle stars, sea cucumbers, and others, it possesses a very peculiar means of locomotion, its tube feet. These are small finger-like structures on the ventral side, or under-side, of each arm. When they are filled with water, they extend from the body until they touch some object. Then some of the water is withdrawn from each tube, thus reducing the pressure inside. The sucker-like tips of the tube feet stick to the support because the water pressure or the air pressure (if the starfish is uncovered) pushes the tube feet against the surface. Thus the starfish can cling to a vertical wall. Also, by holding fast with some of its arms while advancing the rest, it can move slowly about over the rocks. The starfish can also walk on the tips of the bent-over arms and it can swim by moving the arms back and forth.

Importance of echinoderms. The echinoderms are relatively unimportant to man. Starfish interfere with the oyster industry by feeding on the oysters. Sea cucumbers, dried and sold under the name of "trepang" or "bêche-de-mer," are commonly used for food in certain parts of China and in the south-Pacific islands.



General Biological Supply House

A starfish seen through glass, upon which it is walking. Note the tube feet. Can you describe how it walks?

Self-test. 1. Few echinoderms live in salt water.

2. Echinoderms are of *great* economic importance.

3. *Starfish* are used as food in some parts of the world.

4. Select from the following list of animals those which are echinoderms:
(1) starfish; (2) *Pandorina*;
(3) sand dollar; (4) sponge;
(5) jellyfish;
(6) sea cucumber;
(7) basket star;
(8) liver fluke;
(9) pinworm.

WHAT ARE SOME ADAPTATIONS OF THE SEGMENTED WORMS[1] WHICH MAKE THEM ABLE TO LIVE SUCCESSFULLY?

Annelids. The third phylum of worms, the annelids, includes some four thousand species. Many of these are burrowing earthworms and sandworms of various kinds. Another group is made up of leeches of several kinds. Some of these live in the ocean. Others are familiar pests in our streams and lakes. Still other annelids are found in or near the water of streams and seas.

All members of this phylum have bodies that are clearly made up of ring-like sections called segments. This segmented structure is characteristic of the two most successful groups of higher animals, the arthropods and the chordates, which will be described later. Hence this structure marks an important advance over the structures found in the simpler phyla already discussed. The annelids mark another advance in the animal kingdom, for in this phylum we first find animals adapted to life on land.

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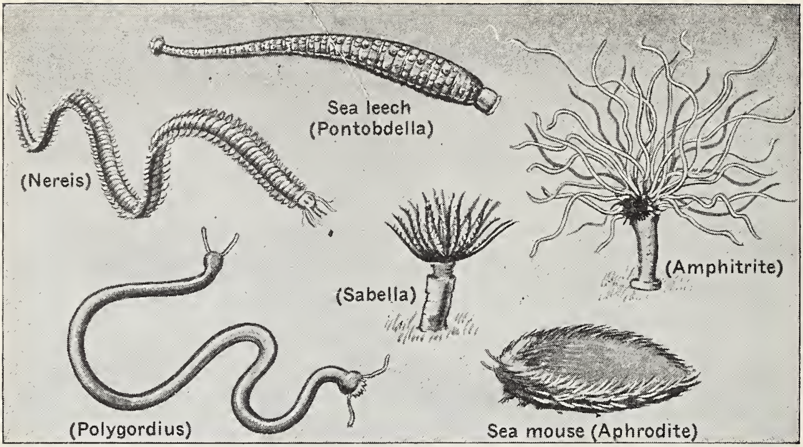
[1] Phylum Annelida.



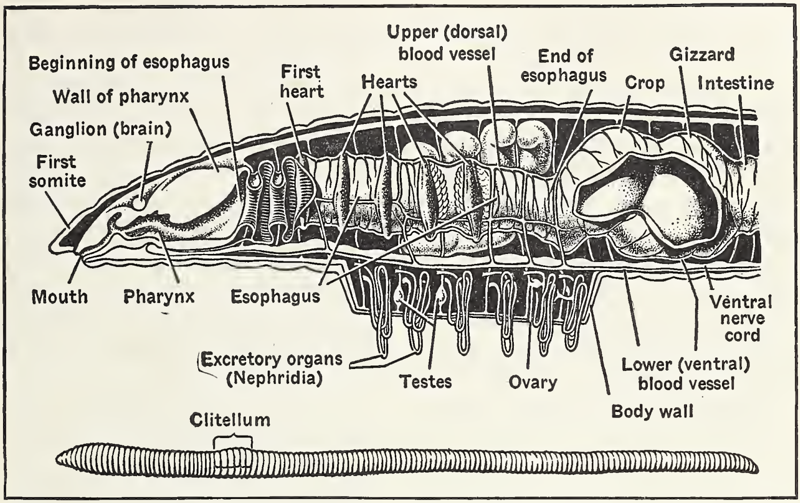
Marine annelids. Can you name a common annelid? There are more different kinds of annelids in this picture than would be found together in their native habitat

Unlike other groups of worms that we have studied, few of the annelids are parasitic. The leeches are temporary parasites; that is, they attach themselves to a frog, a fish, or a man only long enough to suck a meal of blood.

The earthworm, the commonest annelid. The earthworm is abundant almost everywhere that the soil is moist, loose, and rich in organic matter. Its body is long, slender, and cylinder-shaped. Thus it is well fitted for burrowing through the ground.

Experiment 33.[1] How does an earthworm move? Watch a live worm crawling. How can you distinguish the head end? Does the worm always proceed head foremost? How long is the worm when at rest? How long is it when it is stretched out as far as possible? How many small sections, or segments, make up the body? Count the number of segments in other specimens. Is the number the same for all earthworms? Pick up the worm and rub one finger along the under-surface. Can you feel the stiff projecting hairs (setae)? How many of these are there on each segment? Use a hand lens if you have one. What do you infer the function of these bristles to be?

[1] To the Teacher. Experiments 33 and 34 are placed at this point in the text in order that the earthworm may be studied as a complete animal. The results of these experiments may be referred to when various structures and functions are discussed in later sections of the book. It will not be necessary, however, to repeat any portion of these experiments or to make further dissections of this animal.



The internal structures of the earthworm. What internal organs are repeated several times? An organism having many similar structures is said to be primitive

Experiment 34. What is the internal structure of the earthworm? For this dissection[1] use as large an earthworm as you are able to secure. You may use a preserved specimen, or you may kill a worm by putting some ether in the water around it. Stretch the worm out on a pinning pan, or on a piece of board, such as a shingle. With fine-pointed scissors cut through the body wall along the back of the animal, beginning at about halfway back and continuing forward to the head. Pin the body wall back by thrusting pins through it into the wax or board.

Note the fine partitions which hold the body wall in place. Do they bear any relation to the segments? The space between the body wall and the internal organs is the body cavity.

Where is the mouth? Describe it. Trace the digestive system, which consists of mouth, pharynx, esophagus, crop, gizzard, and intestine. Is the intestine coiled, or is it a straight tube? Above the digestive tract find a blood vessel which extends the length of the animal. There is a similar blood vessel below the digestive tract as well. Many smaller vessels connect these two. Near the head end look for the five pairs of hearts, which are merely enlarged connecting vessels. Look closely at the dorsal, or upper, surface of a live earthworm. Can you see the movement of the blood in the dorsal vessel? Does it flow forward or backward?

Now remove a portion of the intestine of the specimen you are dissecting and

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[1] *Dissect* (dĭs sĕkt′): to cut into parts for examination and study. *Dissection* (dĭs sĕk′shŭn): act of dissecting.

examine the floor of the body cavity for the nerve cord. This nerve cord is enlarged in each segment to form a ganglion.[1] The brain is above the pharynx. Locate it.

The earthworm moves by stretching out the anterior, or head, end and then drawing the rest of the body forward. This movement is accomplished by two sets of muscles. One set (circular muscles) runs around the body, and the other (longitudinal muscles) runs lengthwise. If you can imagine two sets of rubber bands in such positions, you will understand the arrangement of these muscles. When the circular muscles in the anterior part contract, the head end is stretched forward. Then the muscles running lengthwise shorten, with the result that the rest of the body is pulled forward. To keep the anterior part of the body from being pulled back, the worm has a number of bristles (setae) which point backward and act like braces to hold it in position.

Importance of annelids. *With the exception of the earthworm, the annelids are of little economic importance. The earthworm, however, eats decaying vegetable matter and also enriches the soil for agriculture with its casts, or feces. Charles Darwin, a noted English biologist, estimated that the earthworms in an acre of ground would in twenty years transfer to the top of the ground a layer of rich soil three inches deep. The numerous burrows made by the worms, moreover, admit air to the soil. The air contains oxygen, which is needed by plant roots.

Self-test. 1. The annelids have *external* skeletons.

2. The annelids mark a higher stage of development than the flatworms, the roundworms, or the echinoderms because they have bodies made up of --?--.

3. The most familiar annelid is the --?--.

4. Select from the following list of animals those which are annelids: (1) leech; (2) sea cucumber; (3) *Hydra*; (4) earthworm; (5) sandworm; (6) tapeworm; (7) trichinosis parasite; (8) *Volvox*; (9) sponge.

5. Annelids are the *lowest* animals which are adapted to life on land.

WHAT ARE SOME ADAPTATIONS WHICH MAKE THE MOLLUSKS[2] SUCCESSFUL ORGANISMS?

Mollusks. You have probably seen in a stream bottom shallow grooves as if made by dragging a twig over the surface of the mud. If you follow one of these tracks, you will find a water snail or perhaps a fresh-water mussel or clam. These animals are mollusks.

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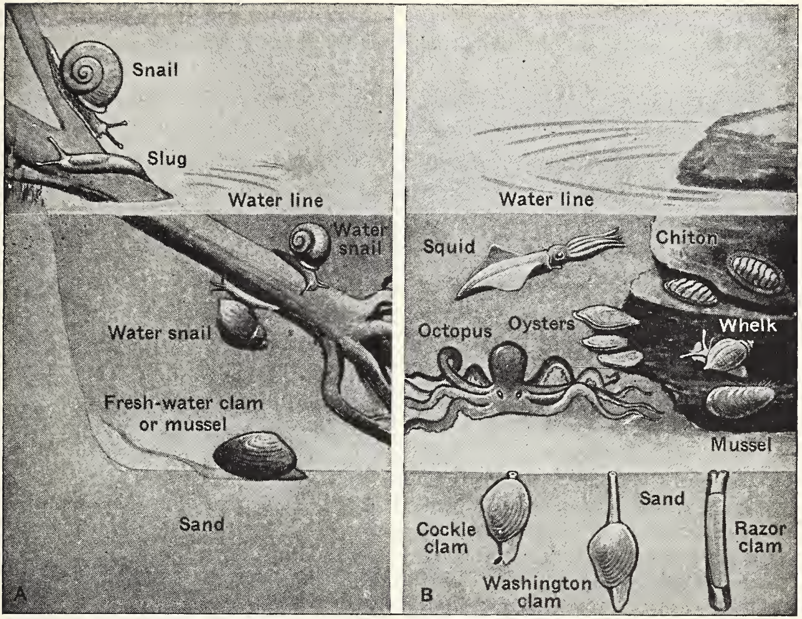
[1] *Ganglion* (găng′glĭ ŭn): a mass, or group, of nerve cells.

[2] Phylum Mollusca.



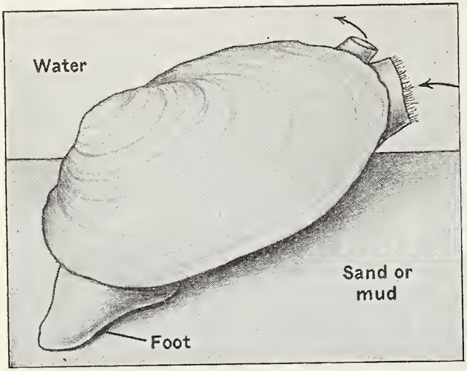
A, fresh-water mollusks; B, marine mollusks. There are more than six thousand species of mollusks. How many mollusks can you name of which man is a dangerous enemy?

*Mollusks are found both on land and in water all over the world. Some of the marine forms—for example, sea mussels, abalones, oysters, and periwinkles—cling to the rocks and other objects along the shores. Clams burrow in the sand of the sea beaches or the sand-and-mud flats of the bays. Other mollusks, like the squid and the octopus, are free swimmers. They are found not only in the shallow water along the ocean shore but also in deep water. Others, like the common snails and garden slugs, live on land.

*All the mollusks have soft bodies which are usually enclosed in a shell. This shell marks the highest development of this type of protective covering. It may be in a single piece, usually coiled, like that of the snail; or it may consist of two halves, like that of the clam.

Every mollusk has an organ called a foot. The snails use this foot for locomotion. The burrowing mollusks use the foot for digging into mud, wood, and even, in the case of the rock oyster, into rock. In the swimming mollusks the foot is modified to form arms. The octopus has eight of these, and the squid and the cuttlefish have ten.

Those mollusks which are enclosed in shells are usually protected very completely. Thus, a clam can draw its body in and close the shell against attackers. Also, a snail can withdraw into its shell when it is molested; but, unlike the clam, the snail cannot close its shell. For this protection, however, these mollusks have to sacrifice speed. "Slow as a snail" is a familiar saying. Perhaps you have watched a fresh-water mussel or fresh-water clam thrust its foot out into the sand and slowly draw its body along. It has no need to hurry. The water brings it food to eat and oxygen to breathe. Moreover, it is so well protected that most of its enemies are not likely to trouble it.



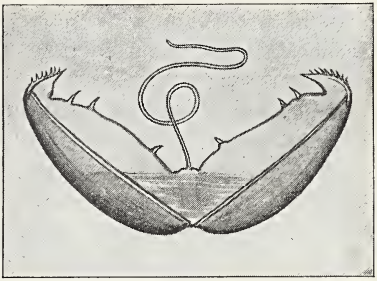
The fresh-water clam, or mussel. Clams do not shed their shells, but grow by adding layers around the edges. Which is the oldest part of the shell? The gweduc clam of Puget Sound sometimes weighs six pounds, and its length from the end of its stretched-out siphon to the other end of its shell may be more than three feet. What survival value may this long siphon have?

The free-swimming mollusks do not have the protection of shells. Hence they must be able to move rapidly if they are to survive. The octopus, the squid, and the cuttlefish may escape from their enemies by swimming quickly away.

Have you ever had the experience, on picking up a clam, of having a stream of water squirted out as the shell closed? If you should examine the animal closely, you would discover that the water came from a tube at the end of the shell. There are really two such tubes joined together, one through which the water enters, carrying food and oxygen, and the other through which it leaves, carrying wastes. These tubes are called siphons.

Life history of the mussel or fresh-water clam. The life histories of some mollusks illustrate complete metamorphosis because the young are free-swimming larvae, not at all like their parents. The life history of the fresh-water mussel furnishes an example. Moreover, it shows an interesting adaptation for survival. The female carries the newly hatched young in her gills. While still very young and almost microscopic, they develop shells and drop off their mother's gills into the water. The shells, which are armed with sharp hooks, open and close continuously. When a fish, swimming by, touches the mussel larvae, the shells clamp together on some soft part of the fish, usually its gills or fins. After the young mussel has become attached, the tissues of the fish's body grow around it, forming a cyst.

For several weeks the young mussel remains attached to the fish's body. During this time it develops most of the structures of an adult mussel. Then the cyst breaks. The young mussel drops to the bottom of the stream or lake to become an independent adult animal.



The larva of the fresh-water clam, or mussel. Is the mussel larva a parasite? Explain

Every kind of mussel has some particular species of fish to which its larvae will attach themselves. No other fish will serve. If the right kind of fish does not happen to swim by at just the right time, the young mussel dies.

The United States Bureau of Fisheries makes use of this knowledge of the life history of the mussel to stock again rivers and lakes from which the mussels have been nearly exterminated. The right kind of fish are put into tanks where there are many mussel larvae, ready to attach themselves to a host. Then the fish are returned to the rivers and in time furnish a new supply of mussels to those waters.

Value of mollusks to man. Oysters are among the most valuable of all sea products. In the United States alone the cost of oysters sold for food runs into millions of dollars a year. In the more thickly populated parts of the world the natural supply of oysters long ago ceased to meet the demand, and various methods of artificial propagation have been used. There are many "oyster farms" in Chesapeake Bay and elsewhere along the Atlantic and Pacific coasts.

Many mollusks other than the oyster are used for food. Marine clams, scallops, and abalones are widely used. Periwinkles and certain species of land snails are eaten by European peoples. Squids are eaten in China and in some parts of Europe and occasionally are found under the name *ink-fish* in our own markets. Squids are favorite bait for cod and for certain other large fish.

The teredo, or shipworm, which is not a worm at all but a mollusk with two shells like the oyster, does great damage to wooden ships and the wooden pilings of wharves. It sometimes burrows in these to a depth of two feet. Often it honeycombs the pilings so as to destroy the foundations of a wharf in a few years.

Many of the buttons that we use today are made from shells of clams and mussels. Until very recent times there was an abundant supply of fresh-water mussels in the rivers of the Mississippi Valley. But after the factories for the manufacture of buttons were established, the mussels rapidly decreased in numbers. Through a knowledge of the life history of the mussels, however, the waters are again being stocked. Intelligent use of the adult mussels, so that fewer are destroyed, will provide for the continuance of this profitable industry.

Several mollusks furnish mother-of-pearl, the beautiful rainbow-tinted lining of the shell. The abalone, especially, supplies particularly fine material used in inlay work. Pearls are formed of this same material. Natural pearls are formed when this material is secreted around some foreign object, such as a parasitic worm or a grain of sand which lodges by chance between the animal's body and the membrane which lines the shell. In Japan and China "culture pearls" are produced by introducing into the pearl oyster small round objects. Perfect pearls can thus be produced more certainly and rapidly than by the natural, chance method. In these same countries small images of Buddha are also placed in pearl oysters. When after a year or so these are removed, they are found to be coated with pearl and are sold as religious images.

The most valuable pearls are formed by the pearl oyster of tropic seas. But true pearls, some of them of rare beauty and valued at many thousands of dollars, have been found in mussels taken from the rivers and streams of the Mississippi Valley and of many other sections of the United States.

Self-test. 1. *All* mollusks live in the ocean or in fresh water.

2. The mollusks mark the highest development of body protection by means of *bones.*

3. *All* mollusks have shells on the outsides of their bodies or shells into which they can draw their bodies.

4. The life history of the *mussel* illustrates complete metamorphosis.

5. Name four edible mollusks.

6. Which animals of the following list are mollusks: (1) shipworms; (2) trichinosis parasite; (3) oyster; (4) clam; (5) mussel; (6) *Paramecium*; (7) sponge; (8) sand dollar; (9) jellyfish; (10) abalone; (11) snail?

Self-test on Important Biological Terms

anterior
aquatic
cilia
dorsal
exoskeleton
invertebrate
metamorphosis
parasitic
primitive
Protozoa
segment
ventral

Galloway

"Tonging" for oysters near the coast of Florida. **Special Report:** The oyster industries of the Gulf of Mexico, the Chesapeake Bay region, and the Pacific coast. (Consult bulletins from the United States Bureau of Fisheries)

Self-test on Biological Principles. 1. Certain species of sponges grow only on the legs or backs of certain crabs. The sponge benefits the crab by protecting and to some extent concealing it from enemies. The crab benefits the sponge by carrying it about, thus promoting freer oxygenation, that is, transfer of oxygen from the water to its cells. What principle of biology developed in an earlier chapter does this association illustrate? Can you state this principle in a complete sentence?

2. In 1899 and 1900 the octopuses became so numerous in the English Channel, probably because of a succession of unusually mild winters and warm summers, as almost to ruin the crab and lobster fishing industries. How does this incident relate to the balance of nature?

3. While the oyster may lay nine million or more eggs in a season, some mollusks lay from twenty to a hundred, and one species as few as fifteen. The eggs of some species hatch in the form of adult mollusks, and the young of one species hatch in the body of the female. Why do not the latter species need to produce so many eggs as the oyster? Can you state the principle illustrated by these facts?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. How might man exterminate the liver fluke? What benefits may result from the work of biologists in discovering all stages of the life history of the liver fluke? Why might it be dangerous to drink water from any stream running through a sheep pasture?

2. Not long ago four members of the same family in one of our great cities died of trichinosis which they had contracted through eating half-cooked pork sausage. Immediately the price of pork fell because many people were afraid to buy it. Was this fear justified? Explain.

3. How does a temporary parasite like the leech differ from a true parasite like the hookworm? from an animal of prey?

4. Can you name the phylum to which each of these organisms belongs: octopus, sponge, *Amoeba*, *Vorticella*, coral, clam, tapeworm, hookworm, sandworm, snail?

5. Which phyla do you know to contain parasitic species?

Exercises on Scientific Method. 1. *Planning Experiments to Find Out whether Certain Conclusions Are Sound.* Have you ever heard people say that worms are rained down? This conclusion is based upon the observation that earthworms are usually found on the sidewalk and in puddles after a heavy rain. How would you proceed to find out whether the worms actually fall with the rain? After you have reached definite conclusions from your experiments, can you explain why the worms are in the puddles?

2. *Making Inferences.* Considering the habitat of the tapeworm, would you infer that it had or had not a skeleton? Check the accuracy of your inference by consulting a college zoology or an encyclopedia.

3. *Inventing Hypotheses.* Can you invent a probable explanation of how the octopus uses the water pressure of the ocean in holding its prey?

Project 11. To secure and observe flatworms. See whether you can find flatworms about half an inch long in near-by creeks and ponds. Put them in shallow dishes of water. Try to feed them with very small pieces of liver. Can you find the two eyespots near the head end? What other organs can you discover? Consult a zoology text for further information.

Project 12. To find out whether "horsehair snakes" really develop from a horsehair. This roundworm, which looks like a horsehair, is often found in moist spots around springs and streams and sometimes around horse troughs. It also lives as a parasite in the body of the grasshopper. Put a horsehair in water and let it stand for a week or so. Does it develop into a living worm, as many people believe it will if left in water? Look up the life history of the horsehair snake in an advanced zoology textbook.

Project 13. To grow snails through the complete life cycle. Collect living land snails from a wooded region or water snails from a pond or creek, or secure land or water snails from a biological supply house. For the land snails put a layer of wet earth in the bottom of a large jar, such as a battery jar. Put in the snails along with a leaf of lettuce for food. For the water snails fill a large jar with water. Put in the snails along with some water weed. Observe the snails from day to day. Make complete notes of all your observations.

Special Reports. 1. What is the Great Barrier Reef of Australia? What are some of the islands that are formed largely by coral? What is precious coral, and where is it found? In what ways might coral reefs and coral islands be of considerable importance to man? (Consult an encyclopedia or a college textbook in physiography or zoology.)

2. What has the United States government done to stamp out hookworm disease? (Consult bulletins secured from the United States Department of Agriculture.)

3. Describe the important characteristics, the life habits, and the economic importance of the gapeworm, which is a parasite in chickens. (Consult a textbook on agriculture or secure from the United States Department of Agriculture bulletins on farm parasites.)

4. To what extent could Victor Hugo's description of Gilliatt's battle with the octopus in *The Toilers of the Sea* be true? (Consult an encyclopedia for facts about the octopus.)

5. Describe the chambered nautilus. What characteristics of this animal do you think inspired Oliver Wendell Holmes to write his poem "The Chambered Nautilus"?

6. Describe the Portuguese man-of-war. How much truth is there in the stories that these creatures can kill a man? Find evidence to justify your statements.

7. How can damage by the teredo, or shipworm, be prevented? (Consult an encyclopedia.)

8. Find out what you can about jellyfish—their size, their habits, their beauty, and the like.

9. How is pearl fishing carried on in various parts of the world?

10. What is cuttle-bone? To what structures of such mollusks as oysters, clams, and snails does cuttle-bone correspond?

CHAPTER XI

Insects and Their Relatives

Questions This Chapter Answers. 1. What are some respects in which all animals of this group are alike? · 2. What are some characteristics of the most important orders of this group? · 3. What are some of the characteristics and adaptations of the crayfish which make it a successful animal? · 4. How are insects classified? · 5. What are some of the characteristics and adaptations of insects? · 6. What are typical examples of incomplete and of complete metamorphosis in insects? · 7. In what respects are insects well fitted for survival?

WHAT ARE SOME ADAPTATIONS OF THE ARTHROPODS[1] WHICH MAKE THEM SUCCESSFUL ANIMALS?

The most numerous animals. Insects, such as flies, mosquitoes, and butterflies, are found wherever we go. Crayfish may be seen in streams. Crabs and lobsters are found along the seashore. Barnacles cover the rocks and the pilings of wharves which are washed by the ocean. Spiders spin webs in our houses and gardens.

These and other arthropods are familiar animals; and it is no wonder that they are familiar, for they include more than a million species. In fact, there are probably more species of them than of all other animals combined. They are common in all but the coldest parts of the world. Different species are found in or upon the ground, in the air, in fresh water, in the ocean, and living as parasites.

The arthropods are ancient animals. They are thought to have appeared on earth at least three hundred million years ago. Fossils of one group (called trilobites) are often found in layers of rock, in pieces of rock along a shore, or in gravel pits. Other fossils have been discovered of insects that thrived during the ages when coal was being formed. These insects were larger than any insects living today but were otherwise much like them. Among these fossil specimens are cockroaches six inches long and dragonflies with a wingspread of two feet. Still other fossils have been found, of ancient gnats, preserved in amber. These are so similar to gnats now living that they can hardly be distinguished from present-day specimens. Indeed, so successful were the ancient arthropods that their body structures have been passed on from generation to generation practically unchanged, through millions of years.

*The arthropods include animals which differ greatly in appearance, in habitats, and in habits of living. Nevertheless they are all closely related because they are similar in structure. Thus every member of this group has an

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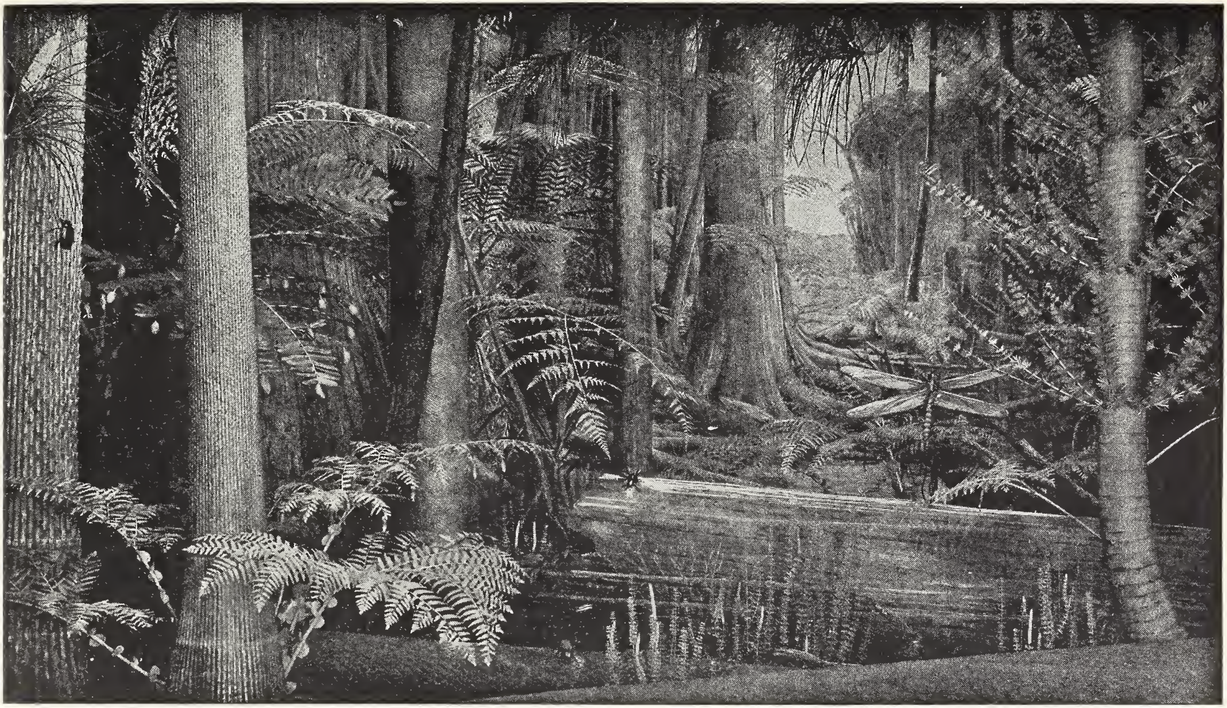
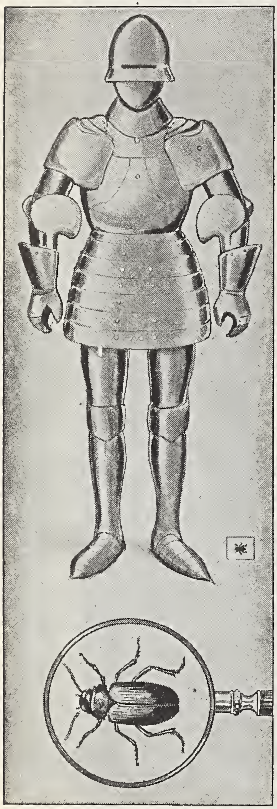
[1] Phylum Arthropoda.



© F. M. N. H.

Plants and animals of the Coal Age. Note the huge dragon fly and the cockroaches. **Special Report:** Life in the Coal Age. (Consult an encyclopedia or a textbook of college geology) exoskeleton which covers it completely like a suit of armor. This exoskeleton is jointed like a suit of armor, so that it permits movement of the various parts of the body. Exoskeletons are shed and new ones are developed by all arthropods as they grow. Every arthropod has a segmented body, that is, a body that consists of conspicuous parts, called segments. Attached to many of the segments are one or more pairs of jointed appendages,[1] such as legs or wings.


Organisms having artificial and natural armor. Compare the advantages and the disadvantages of wearing armor

The classes of arthropods. The arthropods are usually divided into five classes, of which the four most important will be considered here.

1. The Crustacea, or crustaceans, are aquatic animals which breathe by means of gills. The body is divided into two parts, the head-thorax[2] and the abdomen.[2] On the head are two pairs of antennae,[2] or feelers. Attached to the thorax are the legs. The number of legs varies from five pairs in the crayfish and the crab to as many as thirty pairs in some of the very small crustaceans found in our ponds and pools. Many of the larger members of this group, such as the lobster, crab, crayfish, shrimp, and prawn, are used by man for food. These and many smaller crustaceans form the chief food of many fish, especially of young fish. Sow bugs and pill bugs are small crustaceans found in damp places under boards or rocks.

One important member of this group, the crayfish, will be considered more in detail later in this chapter and also at other places in this book.

2. The Insecta, or insects, are such animals as grasshoppers, flies, butterflies, beetles, ants, and fleas. All these have three pairs of legs, never more and never fewer. In the adult stage they usually have wings, though the young, or larvae, may be worm-like. They breathe by a system of air tubes (tracheae). Each insect has one pair of antennae. The body of an insect is divided into three distinct parts: head, thorax, and abdomen. Insects are so important to man that they will be discussed at frequent points in later chapters.

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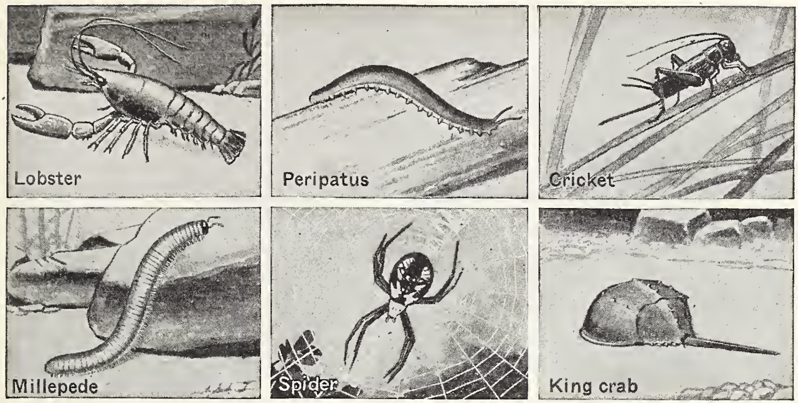
[1] *Appendage* (ă pĕn′dĭj): an external, or outside, organ.

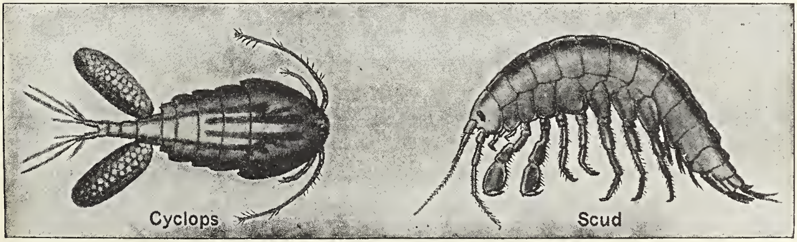
[2] See the Glossary.



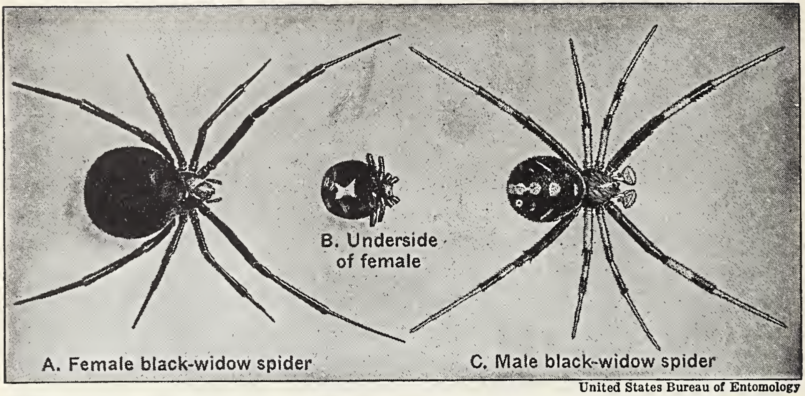
Examples of the classes of arthropods. **Special Report:** Where is *Peripatus* found? How does this animal illustrate "discontinuous distribution"? (Consult a college textbook of zoology or entomology.) The king crab is often classed as an arachnid. It is the last remaining representative of a class that was abundant a long time ago

3. The Arachnida, or arachnids, include the spiders, harvestmen (daddy-long-legs), mites, ticks, and scorpions. The head and thorax are united, as in the Crustacea, giving the Arachnida a very different appearance from that of the insects. The Arachnida have four pairs of legs and no antennae.

Spiders feed on insects and so are beneficial to man. Contrary to popular opinion, very few spiders are poisonous. The black-widow spider produces a painful swelling and sometimes causes death. The tarantula, a large hairy spider which is found in the southwestern United States, is the best known of all the poisonous spiders. Its bite, though painful, is seldom fatal. The scorpion is able to inflict a sting that is painful and slightly poisonous.



These two fresh-water crustaceans are almost microscopic. Are they directly or indirectly valuable to man? Explain



United States Bureau of Entomology

Special Report: The black-widow spider. (See *Bulletin E-245*, Bureau of Entomology, Washington, D. C.)

Such arachnids as mites and ticks are of importance to man because they live as parasites on domestic animals and may carry certain diseases from one animal to another.

4. The Myriapoda, or myriapods, are the "thousand-legged" worms, such as the centipedes and the millepedes. The body of a centipede consists of from fifteen to more than one hundred fifty segments, each of which bears one pair of legs. Centipedes can move rapidly. We may find them under the bark of old logs or under stones. One species is sometimes found in our cellars. They are insect-eaters and so are valuable. Some species, living in the southern and southwestern United States and the Hawaiian Islands, are somewhat poisonous.

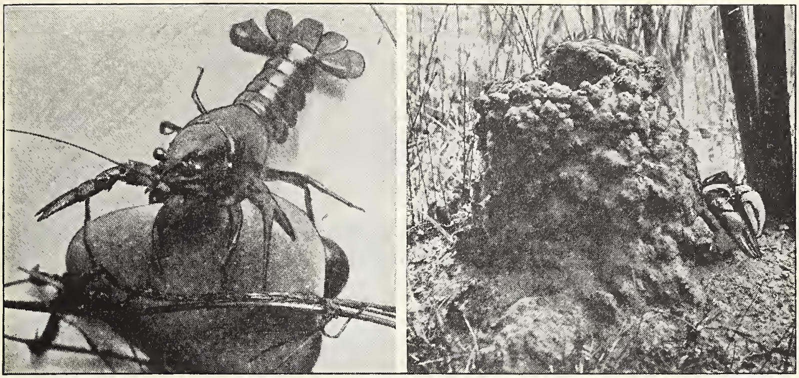
The millepedes are black or brown worm-like animals with two pairs of rather short legs on each segment. They move slowly and, when disturbed, may roll themselves up into a ball. In spite of their rather formidable appearance, they are harmless to man. Millepedes feed on vegetation entirely.

Self-test. 1. As with the annelids, the bodies of the arthropods are made up of --?--.

2. The appendages of arthropods are attached to the *abdomen* in pairs.

3. *Few phyla* contain more species than the phylum which contains the arthropods.

4. Name the four most familiar classes of arthropods and give two common examples of animals in each of these classes.



Cornelia Clarke

Left, crayfish in water; right, crayfish beside "chimney" on land. Some species dig long tunnels in clay banks. One opening is under water and the other is on land with a "chimney" of mud protecting it. How do you explain the fact that crayfish can live for a time out of water?

5. *Some* millepedes inflict poisonous bites.

6. *Most* spiders inflict poisonous bites.

WHAT ARE SOME ADAPTATIONS WHICH MAKE THE CRAYFISH[1] A SUCCESSFUL ANIMAL?

Habitat. The crayfish, or crawfish, is abundant in most fresh-water lakes, ponds, and streams of North America and Europe. Although it is an aquatic arthropod, it can live on land for short periods. Some species are often found on the banks of streams or even at some distance from water. During the day the crayfish hides under submerged rocks or logs or in burrows which it makes in the mud or clay of the banks or stream bottoms. Only the head extends out of the place of concealment, with the antennae and the eye-stalks constantly moving to detect any approaching object. It is active chiefly at night, when it moves about in search of food.

Experiment 35.[2] What are some of the most important characteristics of the crayfish? (Answer the questions in complete sentences or by means of labeled diagrams.)

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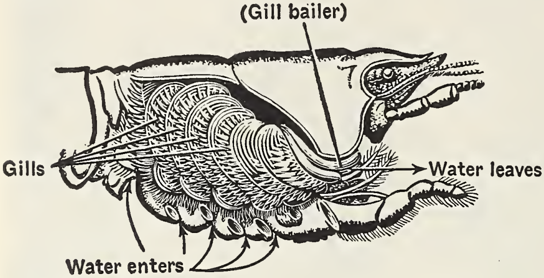
[1] Phylum Arthropoda, class Crustacea.

[2] To the Teacher. This experiment is given here in order that the crayfish may be studied as a complete animal. The results of this experiment may be referred to when discussions of the structures and functions of various organs appear at other points in the book. It will not be necessary, however, to repeat any portion of this experiment or to make further dissections of this animal.

1. How does a crayfish move about? Place a live crayfish on the table. How does it move? Does it use all its legs? Can it move sideways? backward? How does it seem to know where it is going? Do you find any evidence that it is using its eyes? its antennae? Put it into a large vessel of water and thrust a stick or pencil quickly in front of it. How does it move now? What part of its body does it use to produce this movement? Describe. Which of these methods of locomotion would be the more useful in finding food? in escaping from enemies? Which is the more rapid method of locomotion?

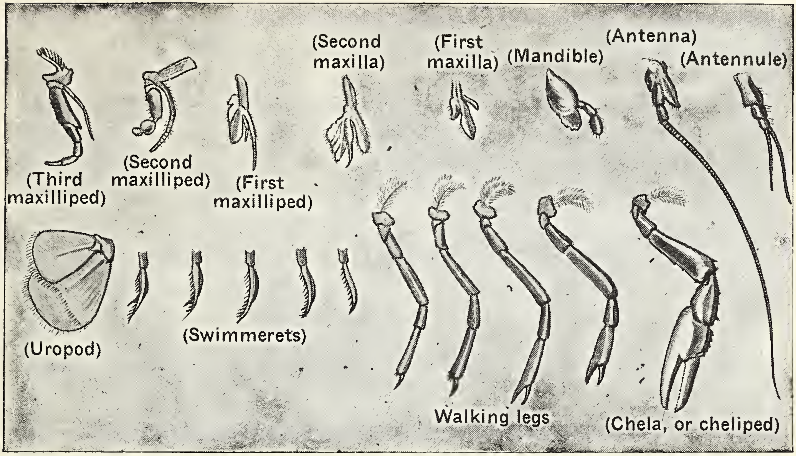


Crayfish gills. What is the advantage of the plume-like structure of crayfish gills?

2. In what respects is the crayfish like the insects? Compare the crayfish with any convenient insect, such as a beetle or a grasshopper. What resemblances do you find between the two? What principal differences? How many body regions does each have? Is the head of each movable? Is the abdomen of each segmented? (The crayfish abdomen looks like a tail.) Does the crayfish have more or fewer appendages than the insect? How many legs does each have? What differences can you see in the different pairs of legs of the insect? of the crayfish? What is the use of each pair as far as you can observe? How many eyes does a crayfish have? Are they like the eyes of an insect? You will find one long pair and one shorter pair of antennae on the crayfish. (The latter are two-parted, appearing at first to be two pairs.) Does an insect have similar antennae? Are the antennae segmented? Do they move readily? Where is the mouth of the crayfish? What movable parts can you see? Describe briefly. Try to get the animal to chew on a piece of paper or a pencil point to see how the mouth parts move. Describe.

3. How is the crayfish protected? Hold the crayfish up in the air. How does it try to get away from you? What is the color of the living animal? Explain the survival value of this color. What are the advantages of having an exoskeleton such as the crayfish has? What are the disadvantages? List all the adaptations for protection. Examine one of the legs of a preserved specimen. How many joints do you find? What is the advantage of having so many joints? In what directions can the leg or its parts move? Squeeze the leg firmly between the fingers. Does it crush easily? Remove the hard covering to expose the muscles of the leg. Try to find where these muscles are attached.

4. How does the crayfish breathe? Hold a live crayfish, ventral side (under-side) up, in a pan of water. (The water should just cover the animal.) Put a drop of ink



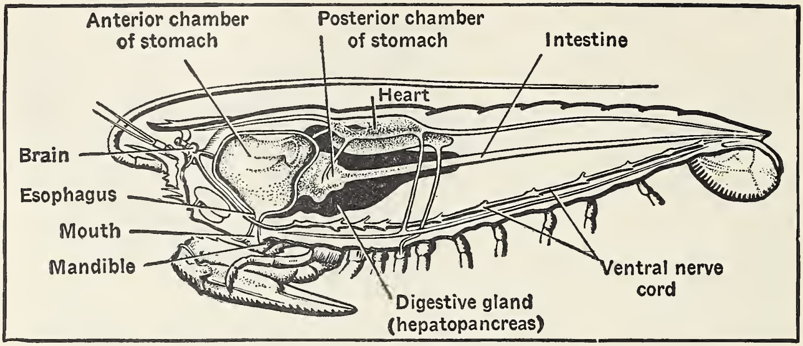
The appendages of a crayfish. The first six are mouth parts. The last five in the upper row are attached to the head; the first six in the second row, to the abdomen; the remaining eight, to the thorax. Can you locate all these on a specimen?

near the base of the posterior (rear) legs. Where does the ink reappear? Repeat this until you can explain what takes place. Make a sketch to show the path of the water bearing the ink.

Use a preserved specimen for these next observations. With scissors cut off the shell (carapace) on one side of the body. The region exposed is the gill chamber. Describe the gills. Cut off the middle leg close to the body, keeping the point of the scissors on the under-side between the leg and the body. What relation do you discover between legs and gills? Put a gill in water. What adaptations for its function of taking in oxygen do you observe?

5. What further facts can you learn of the body regions and appendages? *The head-thorax* (*cephalothorax*). What structures appear when the head is viewed from above? What is the shape of the head? Can the live crayfish move its eyes? Gently touch an eye with your pencil. It will not hurt the crayfish. Why? What happens? Examine the eyes of a preserved crayfish. Of what advantage is the jointed eye-stalk? Draw the head region from above. Make your drawing twice the natural size or larger. Label carefully. Examine the mouth parts. Get help from your teacher to remove the mouth parts. Sketch them and properly label your drawings. Ask to have your work approved before proceeding.

The abdomen. How many segments are in the abdomen? Do all bear appendages? The first two segments in the male have long rigid appendages used in reproduction. Those segments in the female bear small structures (swimmerets) similar to those on the next three segments. Of what use are they? The side-pieces


Anterior chamber of stomach
Posterior chamber of stomach
Intestine
Heart
Brain
Esophagus
Mouth
Mandible
Ventral nerve cord
Digestive gland (hepatopancreas)

Internal organs of a crayfish. What division of labor can you see in this diagram?

of the tail fin are really modified legs (uropods). Note that they are two-parted like the legs and jointed as the legs are. Are they attached to the last or to the next-to-last segment? The last segment (telson) of the abdomen is part of the tail fin. Draw the abdomen, both dorsal (upper) and ventral (under) views, and label all the parts of each drawing.

6. What are the characteristics of the internal structures? Remove the exoskeleton from the thorax region of a preserved specimen. Push the gills aside and carefully cut away the body wall. With the aid of the figure identify (1) the heart, (2) the stomach, (3) the intestine, and (4) the digestive gland (hepatopancreas). Where is the stomach with reference to the mouth? Cut the stomach open. What unusual structures do you find? Of what use are they? Now remove any of the organs mentioned above that may remain. On the floor of the body cavity you can see the white *ventral nerve cord*. Follow it forward to the *brain*, which lies between the eyes.

Special adaptations of the crayfish. *The crayfish has several effective means of protection: (1) It has protective coloration; that is, its color so closely resembles that of the rocks and sand of the stream bottoms that it can be seen only with difficulty when it remains quiet. (2) Its habit of remaining in hiding during the day and of feeding usually at night protects it from such enemies as the wading birds. (3) Its exoskeleton protects it from some fish and turtles and from other crayfish. (4) Its ability to swim rapidly affords it an effective means of escape. (5) Its large claws are formidable weapons for attack and defense.

On land the crayfish seems awkward, though it can move fairly rapidly. Its body seems too heavy for its legs. However, it can walk backward as well as forward. In the water, which partly supports the weight of its body, the crayfish moves very readily. It can quickly change both its direction and its speed. Thus the crayfish walks slowly about in search of food. But if an enemy threatens, it retreats rapidly by bending the abdomen under very quickly and forcibly, using it as a paddle to pull the whole body backward. The jointed structure of the abdomen and the powerful muscles found in it are adaptations that make possible this unusual method of moving.

*The hard exoskeleton of the crayfish does not grow, as does the rest of its body. From time to time the animal molts; that is, it sheds this shell. It molts at least seven times during its first summer and once each succeeding year. After it has shed the old exoskeleton and before the new one hardens, it is without defense. It must therefore remain in hiding. Its chief enemies at this time are other crayfish.

Economic value. Crayfish are considered to be a delicacy in many countries and in some parts of the United States and Canada. They are also of value because they are scavengers; that is, they eat decayed vegetation and dead animals in the water. Crayfish sometimes do damage by digging tunnels in levees. These tunnels so weaken the levees that they sometimes break under the strain of high water.

Self-test. 1. The crayfish is difficult to see in the water because of its --?--.

2. The crayfish *molts* when it becomes too *large* for its shell.

3. The crayfish protects itself from attacks by means of its *sting*.

4. What looks like the crayfish's tail is its --?--.

5. The *crayfish* is used by man for food.

WHAT ARE SOME ADAPTATIONS OF THE INSECTS[1] WHICH ENABLE THEM TO LIVE SUCCESSFULLY?

Insects. Insects are the commonest of all animals. About four fifths of all the kinds of animals known are insects. Over five hundred thousand species of insects have been identified, and new species are frequently discovered and described.

Insects are found practically everywhere. They inhabit the waters of ponds and streams. They fly over or crawl upon the surface of the earth. They live in the shallow waters of the oceans. They have solved the problems of life in the deserts and in the arctic regions. They are so abundant in tropical countries as to present serious problems and to hinder man's settlement of these regions.

Insects live in such different habitats that the wings and legs of different species must vary greatly to enable each kind to survive. Thus a moth has

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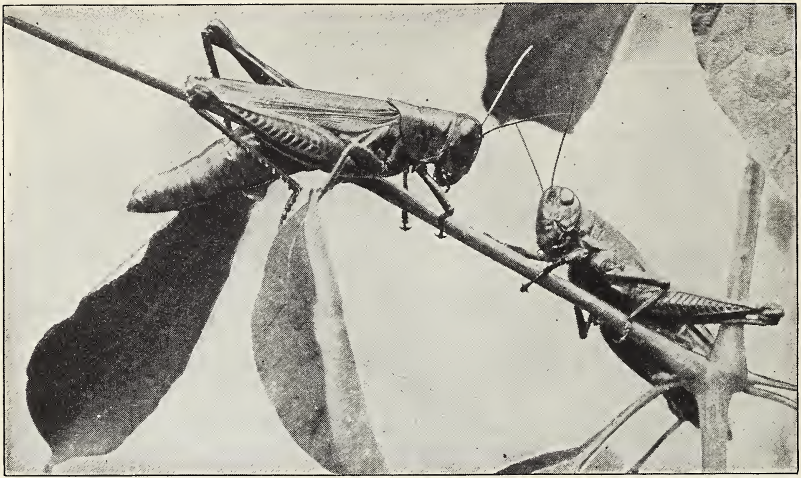
[1] Phylum Arthropoda, class Insecta.



Cornelia Clarke

Grasshoppers. The grasshopper can jump about a hundred times its length. How does its ability to jump aid in its survival?

large wings and small weak legs. Therefore it flies much and walks very little. The grasshopper has long and strong hind legs. These enable it to jump a distance many times greater than its length. Those grasshoppers that can fly as well as jump have well-developed wings. The honeybee has relatively small wings, but these are operated by powerful muscles that enable it to fly at great speed. Aquatic insects, such as water boatmen, diving beetles, and back swimmers, have their hind legs modified for movement in the water.

Experiment 36.[1] What are some of the general characteristics of a typical insect? Use a live grasshopper for these observations.

1. Note the three body regions: head, thorax, and abdomen. How do they differ from one another? Is the head movable? Which part of the body shows most clearly the jointed nature of the exoskeleton?

2. How many legs are there? To what part of the body are they attached? How many wings are there? Lift the outer pair carefully. How do the inner wings differ from the outer wings? To what part of the body are the wings attached?

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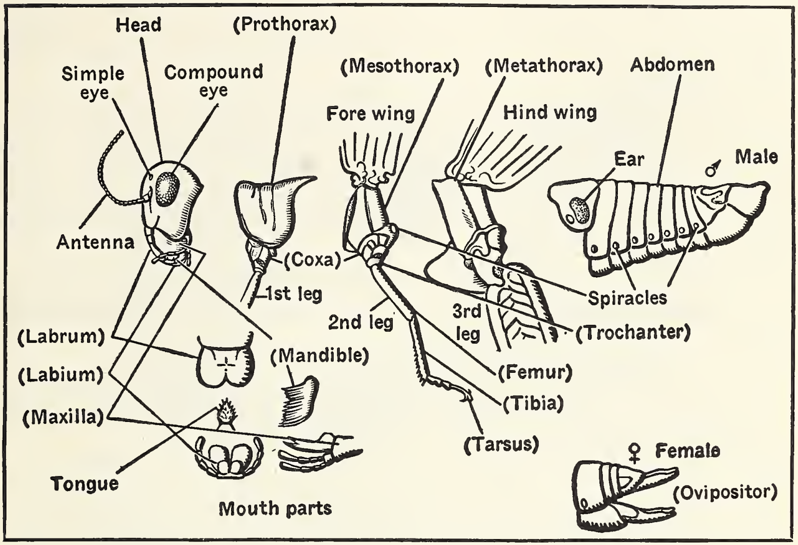
[1] To the Teacher. This experiment is placed at this point in order that the grasshopper may be studied as a complete animal. The results of this experiment may be referred to when various structures and functions are discussed in later sections of this book. It will not be necessary, however, to repeat any portion of this experiment or to make further dissections of this animal.



External structures of the grasshopper. Is the grasshopper on the left in the figure on page 194 a male or a female?

3. Can you observe a movement of the abdomen? The movement is caused by breathing. Look along the sides of the abdomen for the tiny openings (spiracles) which lead to the breathing tubes (tracheae). How many are on each segment?

4. On the head find the compound eyes. Are they large or small in comparison with the rest of the head? Examine with a magnifying glass to see the many small parts which make up a compound eye, or place a piece of the eye of a dead grasshopper under a compound microscope. Near the eyes are the jointed antennae, or feelers. How does the insect use them? Between the compound eyes do you find any simple eyes (ocelli)? How many? Try to feed a live grasshopper a piece of grass. Describe its method of eating. How many mouth parts can you distinguish? How do its jaw movements differ from yours?

Look over the four sections you have just completed and list four or five characteristics by which you think an insect can be distinguished from any other animal. Examine other insects to see whether all possess the characteristics of insects which you have listed.

How insects are classified. There are certain distinct differences between butterflies, grasshoppers, bees, and beetles that enable us to recognize any of them at a glance. Some other insects require more careful study before we can place them with their nearest relatives. Scientists have divided the insects into some fifteen orders on the basis of (1) the kind and number of wings, (2) the kind of mouth parts, and (3) the type of metamorphosis[1] through which they pass.

*Many insects, after hatching from the egg, pass through a complete metamorphosis consisting of three stages: larva, pupa, and adult. Other insects go through an incomplete, or gradual, metamorphosis. An *incomplete metamorphosis* is one in which the changes in appearance as the young develops into an adult are slight and in which the young animal at all times looks much like the adult.

The following table, describing six of the orders which are most important to man, may help you to identify some of the insects you have not previously known:

Order Orthoptera. Four wings, outer pair meeting in a straight line along the back, inner pair folded. Mouth parts adapted for chewing. Incomplete metamorphosis. Examples: grasshopper, cricket, walking-stick, cockroach.

Order Lepidoptera. Four wings covered with scales. Mouth parts modified to form a long sucking tube. Complete metamorphosis. Examples: moth, butterfly.

Order Coleoptera. Four wings, the outer very hard, the inner large and folded. Mouth parts adapted for chewing. Complete metamorphosis. Examples: beetles, like the June bug, potato beetle, firefly, ladybug.

Order Hemiptera. Four wings. The outer wings with the posterior half thin and transparent. Mouth parts adapted for sucking. Incomplete metamorphosis. Examples: squash bug, stinkbug (see "bug" in the Glossary).

Order Diptera. Two wings. Mouth parts adapted for piercing or sucking. Complete metamorphosis. Examples: housefly, mosquito, blowfly, stable fly.

Order Hymenoptera. Four membranous[1] wings. Mouth parts adapted for sucking and chewing. Complete metamorphosis. Examples: bee, ant, wasp.

Complete metamorphosis. The life history of a moth illustrates complete metamorphosis. The colored plate opposite this page shows the life history of the gypsy moth. This insect was brought to this country by an experimenter who hoped that it would prove valuable for silk production. Some of the moths escaped unnoticed. Within twenty years the gypsy moth had become a serious pest of forest trees in Massachusetts and in other states. Fortunately control measures have been developed and, if properly used, will prevent this insect from spreading over all the country.

In July or August, the gypsy moth lays its eggs in masses of four hundred to five hundred, usually on the bark of trees. The eggs remain over winter, hatching about the first of May. The little larva, or caterpillar, begins at once

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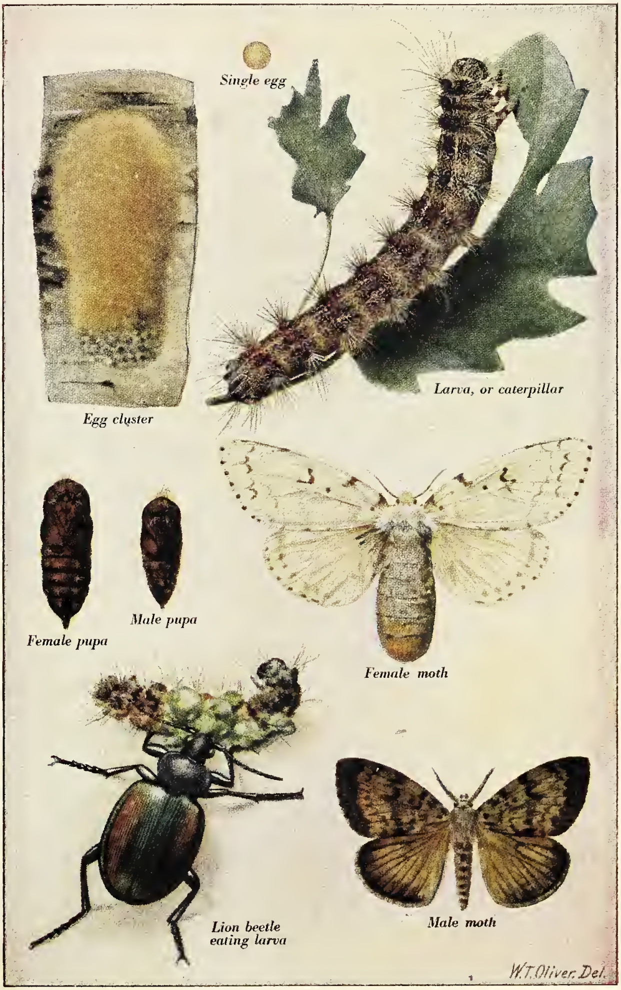
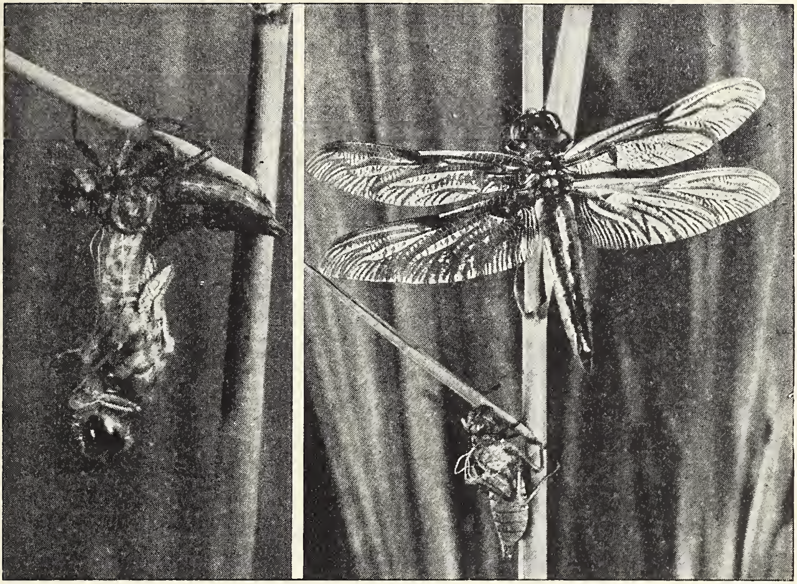
[1] See the Glossary; also, see the Index for an earlier discussion of metamorphosis.



The life history of the gypsy moth.
How does it illustrate complete metamorphosis?



Ernst Krause

A dragon fly emerging from its pupa case (left) and drying its wings (right). What simpler animal likewise undergoes complete metamorphosis?

to eat the tree leaves. It grows very rapidly, molting three or four times. By late summer it has reached a length of about two to two and a half inches. Then it stops eating and crawls about in search of a suitable place to spend the next stage of its life. This is usually a crack in a log, under a piece of bark, beneath a stone, or the like. It spins a few silken threads, which attach one end of the body to a support, or sometimes it spins a complete cocoon about its body. Then the larva within the cocoon molts for the last time and becomes a pupa. It develops a very different sort of covering, the pupa-case.

The pupal[1] stage is often called the resting stage because no activity can be seen. But many changes occur in this period of the moth's life cycle, for within the pupa-case the caterpillar is transformed into a moth. The moth emerges from the cocoon in ten days or two weeks. It lives for a few days until it lays its eggs. Then it dies.

Many of our moths and butterflies pass the winter in the pupal stage. The adult monarch butterfly migrates as the birds do. Some of the anglewing butterflies spend the winter in the adult stage, hiding themselves in brush piles or similar protected spots. Many moths hibernate[2] as larvae or pass the winter in the egg stage. But, for the most part, the pupa affords the best protection against both hungry enemies and the cold. It may be formed under a bit of bark or close against the side of a twig or even buried in the ground. Many of the moths further protect the pupa by spinning a cocoon of silk about it. Some of the moths and all the butterflies pass through the pupal stage in a shell-like case (called a chrysalis).

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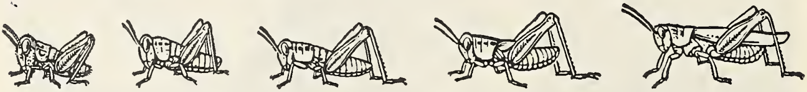
[1] *Pupal* (pū'pl): having to do with a pupa.



Stages in the life history of the grasshopper. How do these pictures indicate that the life history of the grasshopper illustrates incomplete metamorphosis?[1]

Incomplete metamorphosis. The life history of a grasshopper illustrates incomplete metamorphosis. In early fall the eggs of some of the common grasshoppers are laid eight or ten together in holes which the female digs in the ground in pastures, along roads, and in fields. Here the eggs remain all winter. In the central states they hatch about the middle of May.

The young grasshopper (called a nymph) is a queer animal. It has a head and thorax resembling those of its parents, but it has no wings and only one pair of legs sufficiently well developed to be used. It grows rapidly, however, soon reaching as great a size as its exoskeleton will permit. There is but one thing for it to do then—get out of the old armor and grow a new suit. It settles down on the ground or on the grass where it will be hidden from enemies. The exoskeleton splits down the back, and little by little the insect pulls itself out of the old shell. This process of molting may require from twenty minutes to several hours.

While the new skin is still soft and elastic, the insect increases considerably in size. A few hours later, when the exoskeleton has hardened sufficiently, the grasshopper is ready to go hunting for food again. The grasshopper passes through five molts before it reaches adult size.

Factors favoring the survival of insects. It is stated by some scientists that insects are better fitted to survive than other animals, even including man. There are several reasons why insects can compete with other animals so successfully and why they can continue to exist in such large numbers.

1. Their exoskeletons afford excellent protection. In the insect we see the highest development of the exoskeleton. This type of skeleton has several

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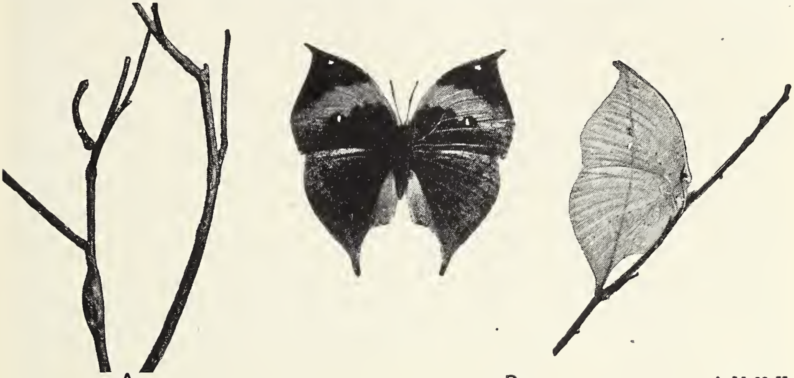
[1] From Packard's *Textbook of Entomology.*

[2] *Hibernate* (hī'bẽr nāt): to pass the winter in a dormant or inactive condition within some shelter. *Hibernation* (hī bẽr nā'shŭn): act or state of hibernating.

marked advantages: (1) It covers the animal completely, thus protecting every part; yet its jointed structure permits freedom of movement. (2) It is sufficiently strong and firm to protect the insect from being easily crushed. (3) It is light enough to enable the jumping insect to leap long distances; yet it is so tough that it does not break when the insect strikes the ground.



A, larva on a twig; B, leaf butterfly on the wing and resting on a twig. What advantages may these organisms derive from such protective resemblance?

The exoskeleton has the great disadvantage that it does not grow as the rest of the body does. Hence it has to be shed from time to time.

*2. Insects are able to escape from their enemies. Both their structures and their habits of living aid them in this: (1) Most insects are small and can crawl into very small shelters, where they will escape notice. (2) Insects have remarkable powers of locomotion. The muscles are attached to the inside of the exoskeleton and are very powerful. Thus a honeybee is said to be able to fly from daylight to dark without rest. Also, ants and wasps may carry other insects weighing much more than themselves. (3) Many insects have protective coloration; that is, their colors blend with those of the environment. Thus many of the caterpillars that feed on vegetation are green. The beetles that live in goldenrod blossoms are yellow. The walking-stick is long and slender like the twig of a tree, which it likewise resembles in color. The grasshoppers commonly found in fields are green, while those of the roadside are brown. (4) Many insects have protective resemblances; that is, they resemble other insects, not only in color, but also in form or in behavior or in both. Thus certain insects, which have no stings or other means of protection, closely resemble bees. Moreover, when molested, these insects make the same motions that the bee makes in using its sting. Still other insects closely resemble in appearance certain forms which birds avoid, probably because the birds have found them unpleasant in taste. Thus the viceroy butterfly, which birds readily eat, is more likely to escape because it closely resembles the monarch butterfly, which many birds have learned to avoid.

In connection with these and other examples of protective coloration or protective resemblance, it must not be thought that any insect or other organism consciously adopts color or behavior in order to secure protection. Moreover, the organism does not purposely seek an environment which affords the best use of the coloration or resemblance that it happens to have. The probable reason that there are so many examples of protective coloration and protective resemblance is that among all the organisms which have lived throughout the millions of years that life has been on the earth, those which happened to have the best protective coloration or protective resemblance survived in greatest numbers and produced others having the same adaptations as themselves. Fewer of those which were without these advantages were able to escape their enemies and to reproduce their kind.

It must be remembered, however, that every living thing has its enemies. Moreover, these enemies find their prey, whether the latter has protective resemblances or not. Protective resemblances alone, therefore, would not enable an organism to survive. Each kind of organism must be able to produce enough young to survive in spite of its enemies. The ability to produce a sufficient number of young is a more important factor in survival than the possession of protective resemblances.

3. Insects are able to use many kinds of food for which few other animals compete. The larvae of certain wood-boring beetles feed on dry wood. The clothes-moth larva eats wool and fur. Bees and butterflies suck the sweet secretion,[1] called nectar, from flowers. The maggot, or larva, of the housefly lives in decaying organic matter.

4. Insects are able to exist for long periods without food. If food is not readily available, many insects can live for months without it. A flea has been observed to live more than a year without food, and yet at the end of that time it was able to hop vigorously.

5. Insects are prolific. Hundreds and sometimes thousands of eggs are laid by one insect. The young of certain species hatch in a few days, and may reach maturity and be ready themselves to lay eggs in two or three weeks. A single housefly, beginning its reproductive activities in early spring, might have over five billion descendants by the end of the summer if all lived and reproduced. It is fortunate that such insects as the housefly have many enemies.

[1] See the Glossary.

A. M. N. H.

A comparison of the American Museum of Natural History and the possible volume of fly descendants from one pair of parents in nine generations. Why are such numbers not really produced?

6. The enemies of insects are sometimes absent, or some insects may have few enemies. Many of the insects that are the most destructive crop pests thrive because their enemies are lacking in the regions to which they have been carried. The gypsy moth is not considered an important pest in Europe, for in Europe there are many birds and insects that feed on it. But when this moth was brought to the United States, it spread very rapidly because sufficient numbers of its enemies were not present in its new habitat to keep it in check.

7. Insects frequently find food in unusual abundance. Man's activities in planting such crops as corn, wheat, and garden plants have resulted in increasing the numbers of insects by providing them with large areas of food. For example, when the pioneers began to settle the Middle West, the Colorado potato beetle was found eating the leaves of wild plants. The settlers cleared land and planted potatoes. The beetle found thus an abundance of food that it liked better than the weeds. It no longer had to hunt for food and could produce brood after brood in the same potato patch. Now it is a pest to every potato-grower in the United States.

8. Insects usually have a protected infancy. Many kinds of insects are protected before maturity by a pupa-case which is hidden underground or under the bark of a tree. Such insects, if not thus concealed, would be easily found, and, since in the pupal stage they are defenseless, would be killed by their enemies. Thus the Japanese beetle, one of the pests recently introduced, passes through the pupal stage in the ground, where it is not easily reached.

Self-test. I. We say that the insect is a very successful animal because (1) every insect is able to thrive in its environment; (2) its exoskeleton makes it difficult to kill; (3) different kinds of insects can fly, crawl, jump, and swim and therefore are widely distributed; (4) insects have been on the earth millions of years; (5) some insects have protective coloration; (6) many insects eat plants.

2. Name three advantages and one disadvantage of the insect exoskeleton.

3. The insect always has --?-- pairs of legs.

4. Which of the following animals illustrate complete metamorphosis: (1) moths; (2) sponges; (3) grasshoppers; (4) butterflies; (5) houseflies; (6) ants; (7) bees; (8) crickets?

5. State eight factors favoring the survival of insects.

Self-test on Important Biological Terms

abdomen
antenna
appendage
exoskeleton
larva
molt
posterior
protective coloration
protective resemblance
segment
thorax

Self-test on Biological Principles. What evidence can you cite from this chapter which tends to prove the principle "Every living thing has enemies among the other living things"?

Self-test on Organization of Facts. Compare the crayfish and the grasshopper (see "How to Study," p. ix).

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Which of the phyla of animals that we have studied thus far is of greatest economic importance to man? Probably not all the members of the class will agree in this choice. Collect from as many sources as you can facts which will help you to defend your selection.

2. In what ways does the ability to move about help the grasshopper?

3. A pantry infested with ants or cockroaches may be freed of the pests by dusting borax freely around on shelves and in cracks. Can you explain?

4. Lobsters and crabs are shipped across the country packed in wet seaweed or straw. How can they live so long out of water?

5. How many different kinds of functions can insects perform with their legs?

Exercise on Scientific Method (Planning New Observations). Dragon flies are sometimes called snake-feeders because of the belief that the insects carry food to sick snakes. The insects are also called darning needles because some people believe that they will sew one's eyes and ears shut. To what questions concerning the structure and habits of the insect should you need to find answers in order to show that both these beliefs are unfounded?

Project 14. To find out whether all insects have the same number of legs, wings, antennae, and the same number and kind of eyes as the grasshopper. Examine with a hand lens or a microscope as many different kinds of insects as you can find—for example, a housefly, a blowfly, beetles of various kinds, a honeybee, a wasp, a bumblebee, a butterfly, a moth. Draw sketches to show the kinds and positions of legs, wings, antennae, and eyes of the various insects. Do the insects of the same order—for example, beetles or flies—have the same kinds and positions of eyes? of wings? of legs? of antennae?

Project 15. To collect as many cocoons and chrysalises as you can find. Store them over winter in a protected place out of doors. In January or February bring them inside and place them in a cage. Try to identify the moths and butterflies that emerge.

Special Reports. 1. Describe the division of labor in a honeybee hive, showing work done by the queen bee, the workers, and the drones. Report on the construction of the honey comb and the brood comb.

2. How do crickets chirp? Do other insects which make noises produce them in the same way?

3. The insect we call a grasshopper is truly a locust. What plagues of locusts have been recorded in history?

4. What is a cicada? a seventeen-year locust?

5. Describe the division of labor in a colony of ants. Compare the organization of a colony of ants with that of a hive of bees.

6. Describe termites and their activities. In what ways do they cause great damage to buildings? How can this damage be prevented? (Consult bulletins from the United States Bureau of Entomology, Washington, D. C.)

7. In making a home garden what insect enemies should you need to know how to combat? Consult garden magazines and bulletins of the Department of Agriculture.

CHAPTER XII

Animals with Spinal Cords

Questions This Chapter Answers. 1. Why were animals classified as they now are? · 2. Are fish ancient or recent animals? · 3. What are some important adaptations of fish? · 4. What are some of the life problems of the Amphibia, and how are they equipped to meet these problems? · 5. What are some facts about ancient and modern reptiles? · 6. Why are birds successful animals? · 7. What are some facts and theories about bird migration? · 8. Are mammals more or less ancient than reptiles? · 9. How are mammals fitted to compete with other animals? · 10. What are the important orders of mammals? · 11. Of what economic importance are these various animals?

WHAT ADAPTATIONS MAKE THE HIGHER ANIMALS[1] SO SUCCESSFUL?

The animals with spinal cords. *All the animals which have been discussed in the preceding chapters are invertebrates. None of the animals in those nine phyla has any bones. Some, such as the echinoderms, the crustaceans, and the insects, have supporting skeletons. But these skeletons are outside, not inside, their bodies. The body of every animal higher than the insect is built around a bony framework which to some extent protects the internal organs and upon which the muscles act to move the body. Moreover, unlike the animals already discussed, all these higher animals have spinal cords on the dorsal, or upper, sides of their bodies. Likewise all but the simplest of these have backbones, that is, vertebral columns. The animals with backbones are the fish, the amphibians, the reptiles, the birds, and the mammals. Attached to the vertebral column of each of these animals are the skull, the bones of the four limbs,—that is, the arms and legs or the fins,—and usually several ribs.

The invertebrates were on the earth many ages before there were any vertebrates. Yet here and there are found fossils of vertebrates which lived millions of years ago.

From very early times it was recognized that the animals which we now call vertebrates could conveniently be classed together. In the fourth century before Christ, Aristotle, a famous Greek, grouped them together as the animals which had blood because he thought that the simpler animals did not have blood. Centuries later it was found that many of the "bloodless" animals did have blood, although in the ones then known it was not red. Because of this discovery the scientists changed their basis of classification and called an animal a higher animal if it had red blood, and a lower animal if it had colorless blood.

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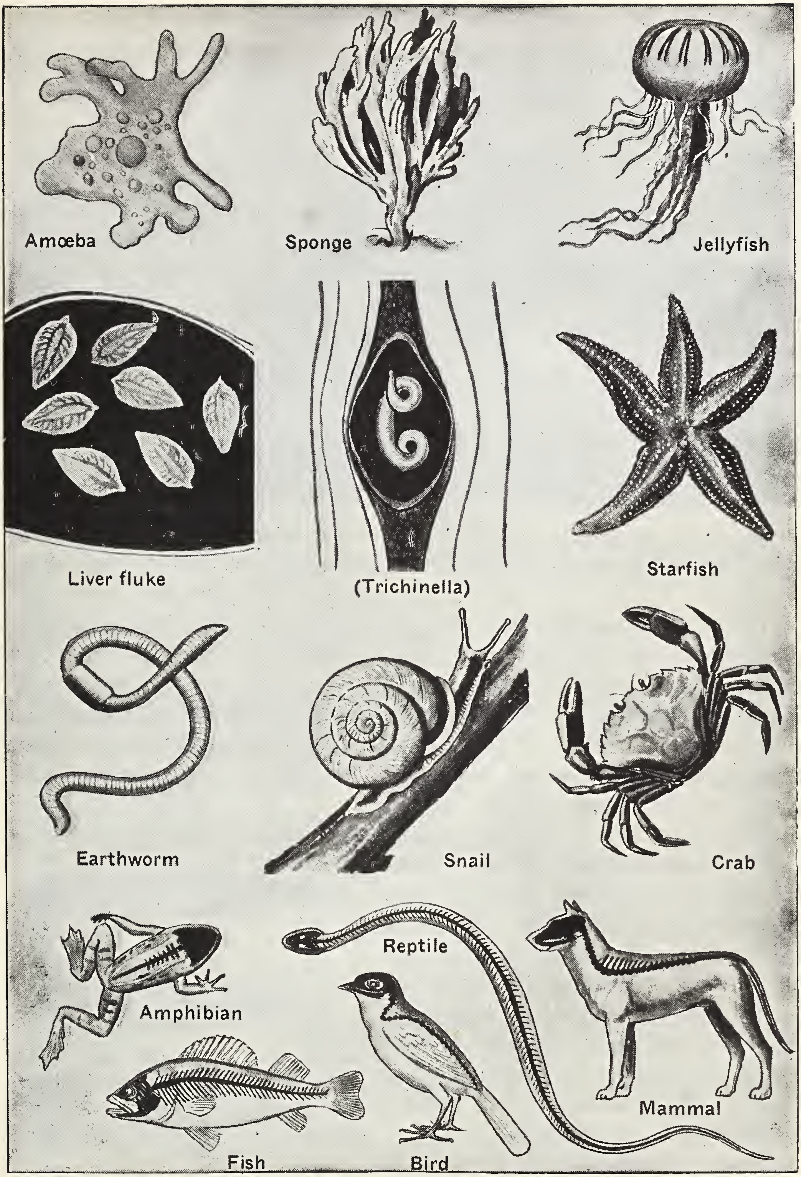
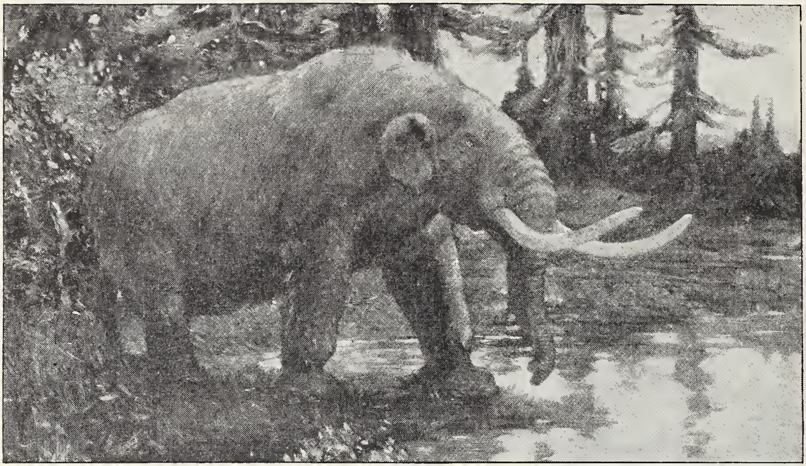
[1] Phylum Chordata.



From the lowest to the highest animals. Self-test on Organization of Facts: Can you name the phylum for each of the first nine of these animals?



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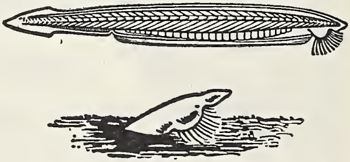
Millions of years ago, this hairy elephant was common in many parts of North America. How many reasons can you suggest which might explain why it has become extinct?

This basis for grouping served until a little more than a century ago. At that time Cuvier, a French naturalist, found that some relatively simple animals have red blood. This discovery made necessary a new way of distinguishing the two great groups. They were next distinguished as bony animals and animals without bones. When later this distinction proved unsatisfactory, animals were classed as vertebrates and invertebrates, that is, animals with backbones and animals without backbones.

The term *vertebrate*, however, has not been entirely satisfactory, because there are certain primitive animals which resemble the vertebrates closely yet have no true bones. A few of these forms (such as *Amphioxus*) are found in the oceans today. They are not fish; yet they resemble fish more than they do any of the simpler animals. They are believed to resemble the ancestors of present-day vertebrates, which were probably fish-like forms living in the ocean.



Amphioxus, or lancelet. **Special Report:** The characteristics of this primitive chordate. (Consult an advanced textbook in zoology or an encyclopedia)

These primitive animals have, in the same position as the backbone of vertebrates, a soft rod-like structure (notochord). This supports the nerve cord along the dorsal side of the body. In fish, which are the simplest vertebrates, and in higher animals as well, the structure which supports the nerve cord is made up of many small bones, or vertebrae. These vertebrae together make up the backbone. The backbone completely encloses and protects the spinal cord.

*Rather than make a separate phylum of the animals which are lower than fish yet are more like them and the higher animals than they are like the invertebrates, biologists have come to use the name *chordates* to include both vertebrates and these simpler forms. The *chordates*, therefore, include all animals which have a nerve cord, whether this cord is supported by vertebrae or by a rod of cartilage.[1]

Self-test. 1. The distinguishing character of the animals in the highest phylum as compared with all others is the possession of a --?--.

2. Some *invertebrates* have colorless blood.

3. Name five groups of animals possessing backbones.

4. The term *vertebrates* includes all the *chordates.*

5. The *vertebrates* are older forms; that is, they have been on the earth longer than the *invertebrates.*

6. Vertebrates are known to have lived on the earth for *hundreds* of years.

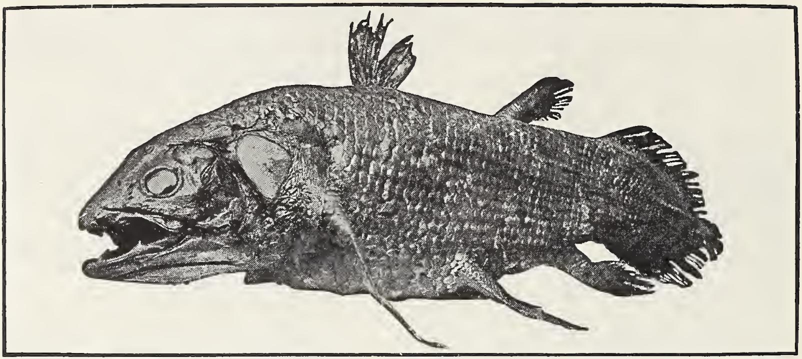
WHAT ARE SOME ADAPTATIONS OF THE LOWEST VERTEBRATES,[2] THE FISH, WHICH MAKE THEM SUCCESSFUL?

Fish are successful animals. At one time in the history of the world, fish were the most conspicuous and most highly developed form of animal life. This period is called the Age of Fishes. Fossil remains of these ancient animals show that they were much like present-day fish. The adaptations which fitted them for life in the water were so successful that they have continued, little changed, for millions of years. Some of these adaptations, which we think of as being peculiarly fish-like, are the fins used in swimming, the gills for breathing, and the covering of scales or plates.

Characteristics of fish. Although most of our fish have bony skeletons, some of the lower forms of fish of the present time have skeletons of cartilage instead of bone. Examples are the sharks and skates. Another group of fish which resembles primitive forms more than it does most of the present forms includes the sturgeon, the gar pike, and certain others found mostly in the

[1] *Cartilage* (kär′tĭ lĭj): a tough elastic animal tissue; gristle.

[2] Phylum Chordata, class Pisces.



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This armored fish (coelacanth) was thought to have become extinct. In 1939, however, a specimen was caught off the coast of South Africa. It was 5 feet long, weighed 127 pounds, and was covered by heavy bony scales. It was thrashing and biting viciously when captured. Compare this fish with the perch, p. 209

Mississippi and the Nile. These are covered with bony plates instead of scales; and in this respect they resemble the armored fish, which lived millions of years ago.

Experiment 37.[1] What are some of the characteristics of a fish? Place a small living fish in a jar of water. Make a sketch of the fish as seen from the side. Label the eyes, mouth, jaws, nostrils, gill covers (opercula), and fins. Compare its external features with those of the perch in the figure on page 209. How many fins has it? Watch it swim. What fin or fins do most of the work of moving the fish? What fins does the fish use in stopping? in turning to one side or the other? Can the fish remain motionless without moving the fins? What fins are in pairs? What are the fins along the dorsal side used for? Does this fish have scales? Are they separate, or does each extend partly over the next, like shingles on a roof? Can the fish move its eyes? Has it eyelids? What advantage does the fish derive from having its eyes placed as they are?

Does the fish open its mouth occasionally or frequently? These movements are part of the fish's breathing. Pull away from the head the gill covers (opercula) of a preserved fish or a fresh fish from the market. Note how the gills are attached. Cut away the gill covers. How many gills are there on each side? Note the filaments, or gill threads. Which way do they point, toward or away from the mouth? Can you see an advantage in this arrangement? Note on the inner edge of the gill arch the

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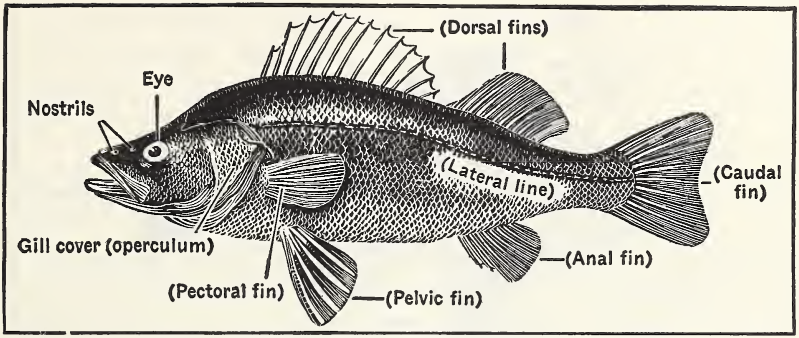
[1] To the Teacher. This experiment is placed here so that the fish may be studied as a complete animal. The results of this experiment may be referred to when the various structures and functions are discussed in later sections of the book. It will not be necessary, however, to repeat any portion of this experiment



External (outside) structures of a fish. **Special Report:** What is the function of the lateral line? (Consult an advanced textbook of zoology)

bony projections (gill-rakers). These strain out food and catch solid objects which might injure the gills. Make a diagram showing the location of the gills. Make another sketch of a gill.

Dissect a fish in much the same way that you dissected an earthworm. Make a sketch and label it to show all the organs you are able to find.

*Most fish need to be able to swim rapidly, both to secure food and to escape from enemies. They have many adaptations which enable them to move quickly through the water: (1) their bodies are more or less flat and taper toward both ends; (2) they are "streamlined"—that is, they have no projecting shoulders or hips to increase friction with the water; (3) the slimy[1] covering over their bodies likewise decreases friction when swimming; and (4) they have an organ filled with air, called an air bladder, which acts as a float, thus reducing the weight of the fish in the water.

When such a fish as the goldfish swims slowly, it seems to be moving all its fins. But when it wishes to move rapidly, it does so by powerful side-to-side strokes of its tail. The other fins seem to be used principally for guiding, stopping, and balancing the animal.

The fins are of two kinds: the single ones on the middle line of the body (as the dorsal, the anal, and the caudal fins), and those that occur in pairs (as the pectoral and the pelvic fins). The paired fins are attached to the rest of the skeleton in the same way as the legs of other vertebrates. For this reason we say that they are homologous to the corresponding limbs of different vertebrates. *Homologous organs* are organs that have the same struc-

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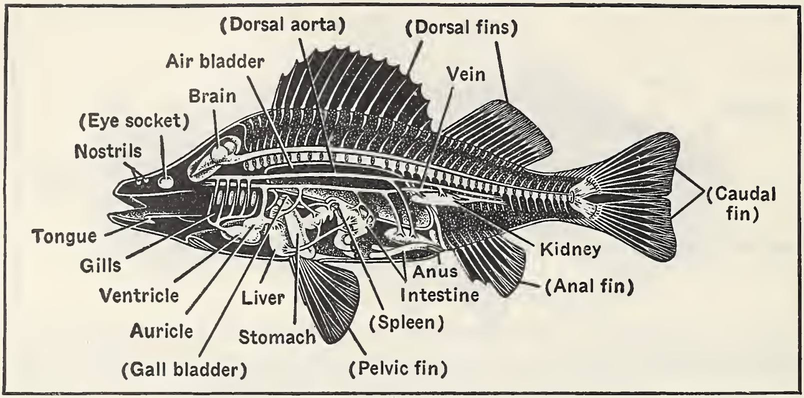
[1] *Slimy* (slī'mĭ): covered with slime. *Slime:* a slippery substance on the bodies of fish, slugs, and certain other animals; a slippery organic substance on stones and sticks in the water.



Internal structures of a fish. What internal organs of the fish are possessed also by the earthworm (p. 175)?

ture or that develop from the same part of the body. The forward pair of fins (pectoral) of a fish, the arms of man, the front legs of a dog, and the wings of a bird are homologous. The lower pair of fins (pelvic) of a fish, the legs of man, the hind legs of a dog, and the legs of a bird are homologous.

*Most fish are prolific. A cod or an eel, for example, may lay as many as ten million eggs at one laying. Why, then, do not cod and eels entirely fill the oceans? Several reasons are apparent. In the first place, all the eggs do not develop into young fish. Then, too, both the eggs and the young fish are eaten in great numbers by birds and by larger fish, crustaceans, and other water animals. Even the parent fish often devour their own young. So many are the dangers that but few ever develop into mature fish.

Economic importance of fish. Fish are chiefly valuable to man as food. Several thousand kinds are eaten. In the United States, Alaska, and Canada the salmon, cod, tuna, and halibut industries are worth many millions of dollars a year. Fish are used extensively for fertilizer and are valuable sources of oil and glue. Oil extracted from fish livers is an important source of vitamins. Isinglass is prepared from the air bladders of sturgeon, cod, and other fish.

Self-test. **1.** In an earlier age fish represented the *highest* development of animal life.

2. *All* fish have skeletons made of bones.

3. The fish which are covered with bony plates instead of scales are a *more* primitive form than those with scales.

4. The *fish* has two pairs of fins which are homologous to arms and legs.

5. Fish are of chief importance to man as __?__.

6. Fish lay *few* eggs because the chances that each egg will develop into an adult fish are very *small.*

WHAT ARE SOME ADAPTATIONS OF THE FROGS AND THEIR RELATIVES[1] WHICH MAKE THEM SUCCESSFUL ORGANISMS?

Characteristics of the Amphibia. *Amphibians occupy a position between the water-dwelling vertebrates and the land-dwelling vertebrates. The word *amphibian* means "an animal that lives a double life." This meaning refers to the fact that the young of most of the species—for example, the frog and the toad—are hatched in the water and breathe with gills, while the adults live on land and breathe both with lungs and through the skin. The adults of many of the lower forms, however,—for example, the mud puppy,—breathe with gills all their lives.

Some of the amphibians resemble snakes. Others, as the newts and salamanders, look like lizards. But, unlike snakes or lizards, most of the amphibians have smooth, slimy skins without scales. All go through complete metamorphoses; that is, they develop from the egg into a tadpole stage, which is very different from the adult.

How toads and frogs develop. The development of the frog is similar to that of all other amphibians. Members of the frog family are prolific. One toad observed in the laboratory laid 6350 eggs in one night. Frog and toad eggs are fertilized by the male as they leave the body of the female. The young develop in a week to ten days. If you watch carefully from day to day, you can observe some of the changes shown in the figure. The young tadpole fastens itself to weeds or sticks in the water by a sucking organ on its head. At first it has neither gills nor mouth. Consequently for a few days it absorbs oxygen through its skin and is nourished by the yolk of the egg from which it developed and to which it is still attached. Soon external gills and a mouth develop. Now it swims about, using its tail as a fish does. It eats large quantities of plant material, such as algae.

You will have to watch carefully in order to observe the external gills, for they are absorbed by the end of three or four days. By that time internal gills have developed to take their place. These are covered by a fold of skin (the operculum), as in the fish. The water enters the mouth, passes over the gills, and out through a single opening (spiracle) on the left side of the body.

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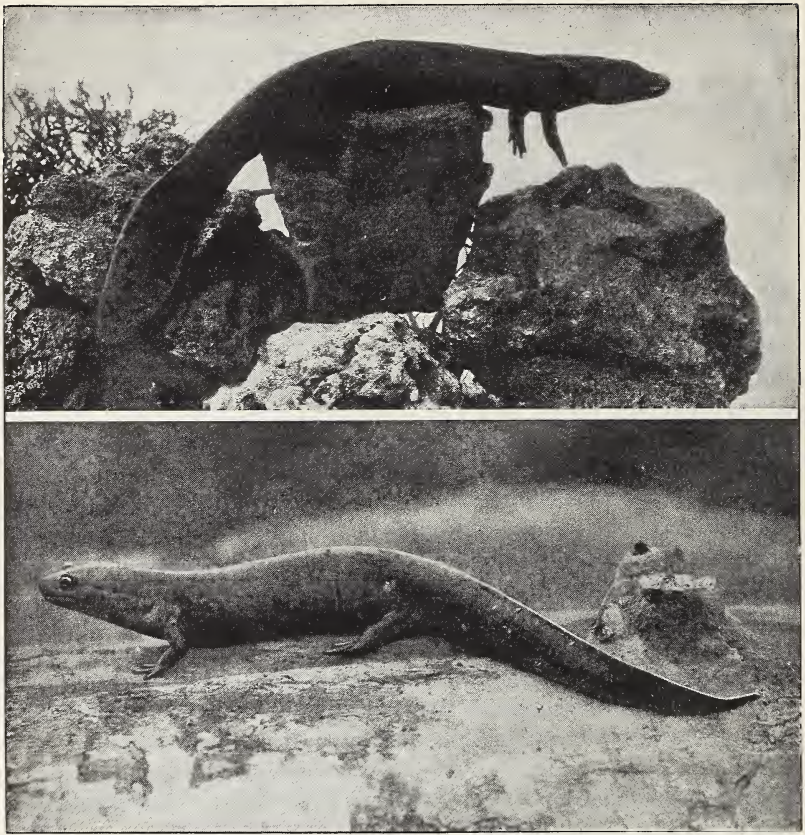
[1] Phylum Chordata, class Amphibia.



New York Zoological Society and L. W. Brownell

Two lizard-like amphibians. Upper, mud puppy in the water; lower, red salamander on a log. **Exercise on Scientific Method (Making Inferences):** Which of these amphibians do you think has gills? Explain. What purpose do you think is served by the broad tail of the mud puppy? Why do you infer this?

The tadpole increases in size rapidly. Soon the hind legs appear. At first these appear as little bumps near the tail. Gradually they get longer and assume their final form. Somewhat later the front legs break through the skin. They are formed at the same time as the hind legs, but remain beneath the skin for a while. All this time the tail has been getting shorter and shorter. It is gradually absorbed, and the food material stored in it is used to make other parts of the body.

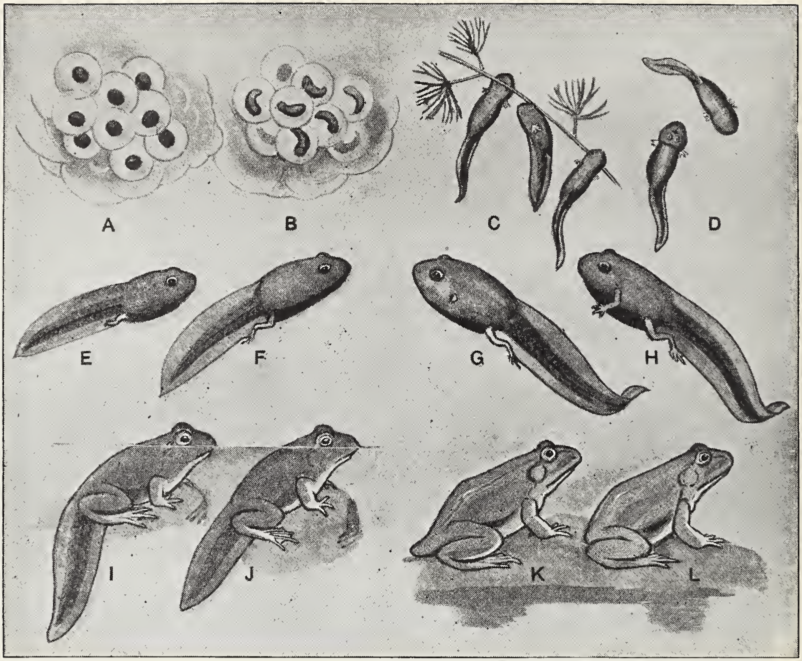
Lynwood M. Chace

Leopard frog and its eggs. The leopard frog is prolific. Part of the egg mass here has been lifted above the water in order that it might be photographed. How do you explain the fact that the egg mass is larger than the frog?

Equally important changes have been going on inside the body of the tadpole. The lungs develop as the gills disappear. A time comes when the tadpole has to come to the surface to breathe. The very young tadpole eats plant material almost entirely. It therefore has the very long coiled intestine which is characteristic of plant-eating animals. As it grows old enough to eat insects and worms, which are more easily digested than plants, the intestine becomes shorter. The mouth changes greatly, too. The rather small rounded mouth of the tadpole, which was used to suck off pieces of plants, becomes large and of a different shape, better adapted for catching insects and worms.

When all these changes have occurred, the little frog or toad hops out on land. The length of time required for a tadpole to become an adult depends on the species and to some extent on the amount and kind of food available. Toads develop in two or three months. Most frogs, like the leopard frog, complete their development before the end of the summer. Green frogs and bullfrogs live two or even three years in the tadpole stage.

The metamorphosis of the frog or toad indicates that its ancestors were water animals. The fish-like tadpole, which can live in water only, develops



The life history of the frog. Can you explain this series of diagrams? Does the life history of the frog, like that of all other Amphibia, represent a complete or an incomplete metamorphosis? Explain

into a frog, which can live on land and breathes air. This development of the frog offers evidence that slowly, over long periods of thousands of years, the fish-like ancestors of the frog became adapted to life on land.

Some adaptations of the frog. The frog has many adaptations which make it a successful animal. Some of these can be readily observed.

Experiment 38.[1] **1.** What are some adaptations of the frog? Place a frog in a jar containing five or six inches of water. In what position does it float? What parts of the body remain above the water line? Of what advantage is this position? Move your hand quickly toward the frog. What happens? Describe. Do you infer that

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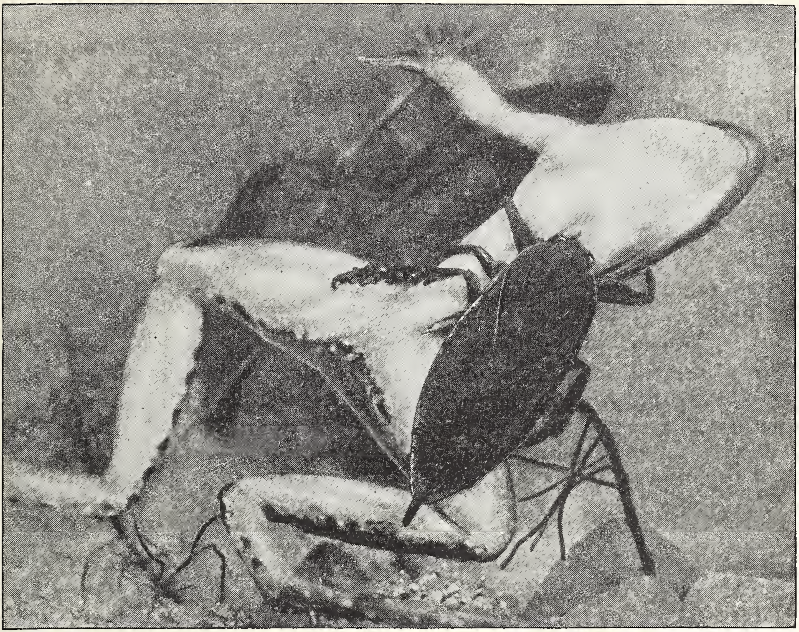
[1] To the Teacher. Experiments 38 and 39 are placed here so that the frog may be studied as a complete animal. The results of these experiments may be referred to when various structures and functions are discussed later in the book. It will not be necessary, however, to repeat any portions of these experiments or to make any further dissections of this animal.



Lynwood M. Chace

The giant water bug finds its prey. How many kinds of enemies of the frog can you name which attack it out of water? under water?

water serves as shelter for the frog? Look closely for the transparent third eyelid (nictitating membrane) which the frog can draw over its eye when under water. Of what advantage is it?

2. How can the frog stay so long under water? Place a frog in a jar of water. When it dives under and rests on the bottom, time it to see how many minutes it stays down. How does this interval compare with the length of time man can remain under water? Can you account for the difference?

3. How are the legs fitted for swimming and jumping? Carefully examine the legs of a live frog. How many toes are there on each foot? Are both hind and front feet webbed? Put the frog in water, so that it can swim. How does it use its legs? Place it on the floor and watch it walk or jump. For what does it use each pair of legs now? Repeat until you are sure your answer is right.

Make a sketch of the hind leg of the frog and beside it place a sketch of your own leg. Which parts of the frog's leg are longer in proportion to the total length than are the corresponding parts of your own leg? How would this form of leg help in swimming and in jumping?

How are the bones moved? Remove the skin from the leg of a preserved frog. Note especially the large muscles of the upper leg. Examine one of these closely. Where is it attached to the bones of the leg? How does the muscle help to move the bones? Note the tendons that extend from the muscle across the joint. What is their use? Can you find a muscle which draws the leg up? one which straightens it out? Make a diagram to answer the question asked at the beginning of this paragraph.

Internal structure of the frog. The frog provides a good illustration of the internal structure of a vertebrate. All the higher animals, including man, have bodies built on much the same plan as that of the frog. Note carefully these structures in the figure.

Experiment 39. What is the internal structure of a frog? Use a preserved specimen or kill a frog with chloroform. With the scissors remove the muscular wall of the entire ventral surface of the abdomen. Keeping the point of the scissors high so as not to injure internal organs, cut through the structure that supports the front legs (the pectoral girdle) up to the throat, so that the heart is exposed.

Describe the heart. Is the heart farther anterior (toward the front end) or posterior (toward the rear end) than yours?

Locate and describe the lungs. In a fresh specimen put a tube into the opening in the throat and fill the lungs with air.

Where is the liver? How many lobes has it? Can you find the gall bladder?

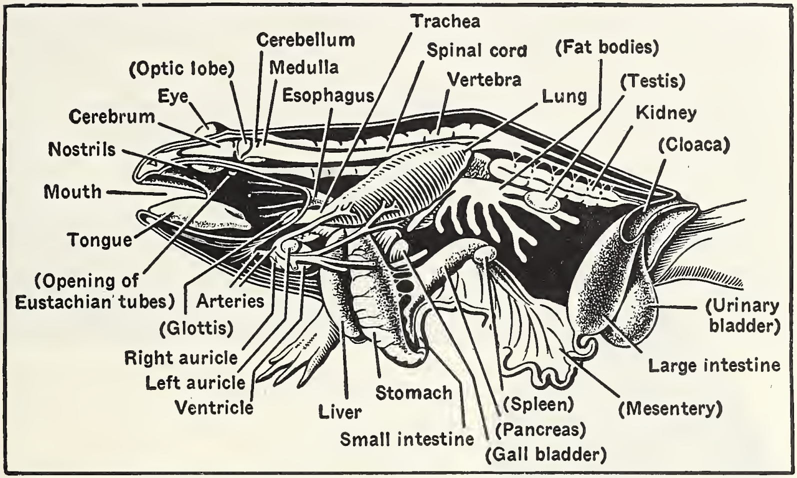
Trace the organs making up the alimentary canal (or food-tube)—mouth, esophagus, stomach, small and large intestine, and cloaca. In the loop between the stomach and intestine find the pancreas.

Did you notice the thin tissue (mesentery) that holds the intestine in place? Look for blood vessels in it. Look also for the spleen, near the large intestine but not connected with any organ.

The kidneys are large dark-red bodies on either side of the vertebral column. Near them you may find irregular finger-like masses of fat. The presence of these will depend on the time of year. Why? What function do you think these fat bodies might serve?

What are the parts, or organs, which make up the nervous system of the frog? Along the back find several large white cords which come from between the vertebrae of the spinal column. These are nerves. Trace them for some distance. Where do they go? What muscles do they control? Now turn the frog over, so that you are looking at the top of its head. Remove the bone carefully from the top of the skull, exposing the brain cavity. Notice the membrane covering the brain. Can you find blood vessels in this membrane? Locate the parts of the brain by consulting the figure.

Enemies. Besides man, who eats frogs' legs, the enemies of frogs include various birds and a few insects. The frog cannot fight its enemies. It must



The internal structures of the frog. What internal structures do the frog and the fish (p. 209) have in common?

therefore depend on its protective coloration to conceal it; or it must escape by jumping or swimming away or by hiding. It may leap into the water and either swim some distance or rest on the bottom until the enemy has gone.

Some amphibians—for example, the leopard frog, the toad, and certain of the newts and salamanders—have poison glands in the skin. Some animals are made very sick or may even die as a result of eating these amphibians.

Economic importance of Amphibia. *Practically all the Amphibia are of more or less benefit to man. Frogs are of considerable value, since they eat insects that would trouble man. But the toad is the most useful member of this class. It lives in our gardens, about our homes, or even in greenhouses and destroys countless insect pests. No less than eighty-three species of insects have been found in the stomachs of toads. One investigator estimated that a toad may eat twenty dollars' worth of cutworms (the larvae of certain moths) in a summer, assuming that each worm does only one cent's worth of damage.

Self-test. 1. *Some* amphibians develop through *incomplete* metamorphosis.

2. *All* amphibians have four legs.

3. *All* amphibians breathe with gills during at least a part of their lives.

4. As a tadpole develops, its tail *drops off*.

5. From the life history of the frog, scientists believe that the *frog's* ancestors lived in the water like fishes.

6. A frog can sometimes escape being eaten by other animals because of its (1) poison glands in the skin; (2) protective coloration; (3) ferocious appearance; (4) formidable teeth; (5) spines.

7. The amphibian of greatest economic importance is the *salamander.*

HOW ARE THE SNAKES AND THEIR RELATIVES[1] EQUIPPED FOR SUCCESSFUL LIVING?

Ancient reptiles. At one time in the history of the world, many millions of years ago, the reptiles were the largest and perhaps the most numerous animals. Gigantic land-dwelling reptiles, called dinosaurs, roamed the land. Fantastic reptiles, somewhat resembling snakes, lizards, or fish, inhabited the waters. Flying reptiles, some with a wing-spread of twenty feet, glided through the air. Skeletons have been found of a huge plant-eating animal measuring eighty feet from nose to tail tip and weighing nearly forty tons. It must have lived in the water, for it seems impossible that it could have carried such a huge bulk about over the land. Preying on such animals were smaller forms—smaller only by comparison, however, for certain ones stood twenty feet high and had teeth six inches long. All dinosaurs, however, were not great monsters like *Tyrannosaurus* and *Diplodocus* (see the figure, p. 37). Some were no larger than present-day lizards. Further information concerning these reptiles was gained a few years ago when a scientific expedition into the desert regions of Mongolia found several fossil dinosaur eggs.

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Fossil dinosaur eggs. The ancient reptile that laid these eggs was about the size of a present-day crocodile. The eggs are about eight inches long. **Exercise on Scientific Method (Constructing Hypotheses):** Can you think of one or more reasons which might explain why the eggs did not hatch?

During the long period in which these animals were dominant, conditions slowly changed. The swamps slowly dried up, and vegetation became much less abundant. The huge reptiles were unable to adapt themselves to the changing environment. Hence they finally became extinct. It is thought, too, that the small mammals which were just then coming into existence may have fed upon the eggs of the great reptiles, thus hastening their disappearance from the earth.

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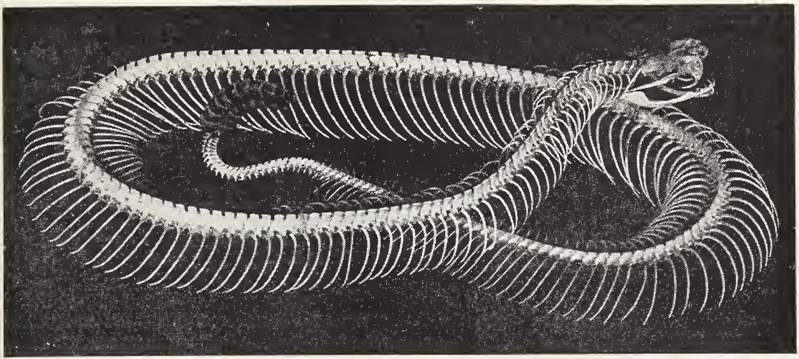
[1] Phylum Chordata, class Reptilia.



General Biological Supply House

The skeleton of a rattlesnake. If you found such a skeleton, could you at once place the animal in its correct phylum even if you did not already know to which phylum it belonged? Explain

A few of the reptiles of earlier ages changed sufficiently, as the environment changed, to be able to survive. They were the ancestors of our present-day reptiles, and probably of the birds as well.

Modern reptiles include some large forms. Certain sea turtles may weigh five hundred pounds. The python of Burma, which is the largest of snakes, sometimes attains a length of more than thirty feet.

Characteristics of reptiles. *Unlike the amphibians and the higher vertebrates, the reptiles are wholly covered with scales. A characteristic that further distinguishes them from the amphibians is that they have lungs throughout their lives. This latter character marks an advance over fish and amphibians, for the lungs enable the reptiles to breathe air at all times and hence make it unnecessary for them to live always in or near the water. It is only as animals have developed structures which have made them independent of the water for support, for food, and for oxygen that they have been able to live successfully far from rivers, lakes, and oceans. Only thus has it been possible for animals to live in deserts, on mountains, and on high plateaus.

The reptiles have no metamorphosis, as the amphibians have. When the young hatch, they closely resemble their parents. Nearly all reptiles lay eggs, which resemble birds' eggs, except that the covering is leathery instead of hard and brittle. The eggs are placed in some protected spot, as in a hole in the dirt or sand, under a pile of leaves, under fallen trees, or even in a hollow decaying tree. Usually the parent pays no further attention to the eggs or young, though a few kinds of snakes guard their eggs and young for a time. Some snakes, including the garter snakes and the rattlesnakes, and one lizard (the horned toad) keep the eggs within the body until they hatch. The young of these reptiles, therefore, are born alive.

The orders of reptiles differ considerably because of the adaptations necessary to enable them to survive. For example, snakes, having soft unprotected bodies, must be able to move rapidly, while turtles, protected by a hard shell, find speed unnecessary. The alligators and crocodiles and some snakes and turtles are adapted for spending most of their time in the water. The horned toad, a few kinds of snakes, and certain tortoises are adapted for life in the desert.

Snakes. Snakes are probably the most feared and disliked of animals. Many people wish to kill every snake they see. A small child, however, is by nature no more afraid of a snake than it is of a dog or other animal. It learns to be afraid through watching the actions of older people and being told that a snake will bite or that it is poisonous. In regions where there are poisonous snakes perhaps such teaching is necessary. But very few of our common snakes will harm one in any way. Most of them are timid creatures that are much more afraid of man than he should be of them. They will usually hurry to some safe hiding place if we will leave them alone.

Snakes are very useful animals. Many common small snakes are of benefit to man because they eat insects. Somewhat larger snakes, such as the bull snake and king snake, eat rats, mice, and rabbits. It is said that one bull snake is much more effective than several cats in keeping a barn free of rats and mice.

Of the four kinds of poisonous snakes found in the United States, the rattlesnake is the most common. Species of it are found in practically all parts of the United States and in parts of Canada. The copperhead is found chiefly in the eastern parts of the United States. The water moccasin, or "cottonmouth," is common in and along the streams and lakes of the South. The coral snake is confined chiefly to the South. It is not very common.

The rattlesnake, the copperhead, and the water moccasin are most readily identified by their triangle-shaped heads, which are almost as broad as long. The shape of the head makes it appear that these snakes have necks. Other characteristics are a pit between the nostril and the eye and eyes with slit-like pupils. Only the rattlesnake has rattles, but the copperhead and the water moccasin, when angry or frightened, will often vibrate[1] their tails in the same way as a rattlesnake.

These three snakes have such good protective coloration that one is likely to step near them without seeing them. The coral snake, in contrast, is readily seen. Only the rattlesnake gives warning of its presence. The bite of any of

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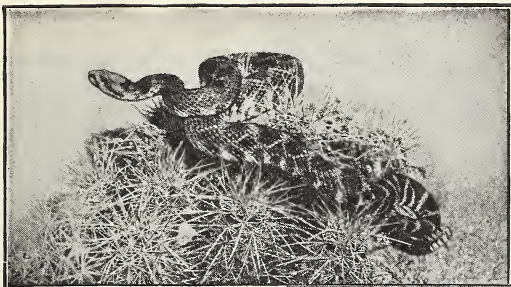
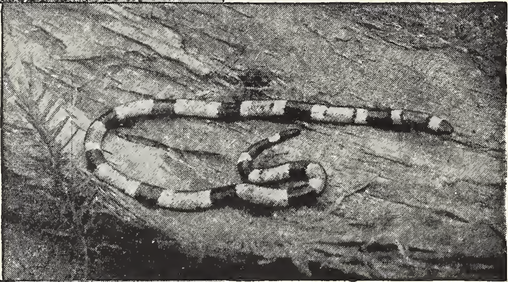
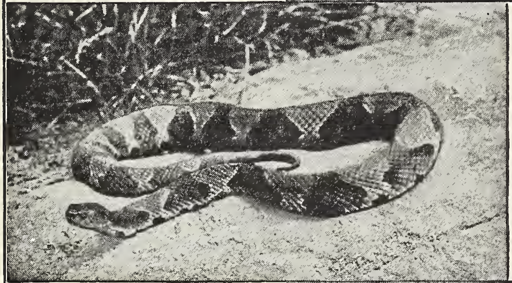
[1] *Vibrate* (vī'brāt): to move back and forth. *Vibration* (vī brā'shŭn): the act of vibrating.



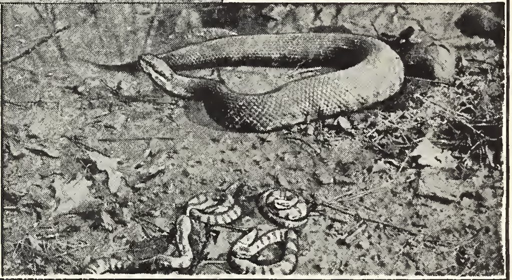
Rattlesnake on a cactus



Coral snake



Copperhead



Water moccasin and young

Top, John Edwin Hogg; the other three, New York Zoological Society

Four poisonous snakes of the United States. Of these only the rattlesnake is found in Canada. How would the protective coloration of a poisonous snake be of value to the snake itself but a disadvantage to other animals, including man?

these snakes is serious, but it is not often fatal. In case one is bitten, a tourniquet (see page 527) should be tightly tied above the wound. Then the wound should be cut deeply so that it will bleed freely. The tourniquet should be loosened every fifteen minutes to permit blood to flow through the tissues around the wound. Potassium permanganate or silver nitrate should be applied to the wound. One should seek a doctor at once.

Except for a few species of amphibians and of lizards, snakes are the only vertebrates which lack legs or similar appendages. The skeleton indicates, however, that their ancestors possessed legs. Snakes move by means of the large scales (scutes) on the under-side. These grip the ground and hold the animal in position, while the muscles which run lengthwise in the body contract in a series of waves to help in moving.

Often while observing a snake we may see it stick out its forked tongue and vibrate it very rapidly for a moment. Some people think that the animal is trying to harm them. They do not know that the tongue is very soft and sensitive, and is thought perhaps to be an organ of hearing as well as an organ of touch.

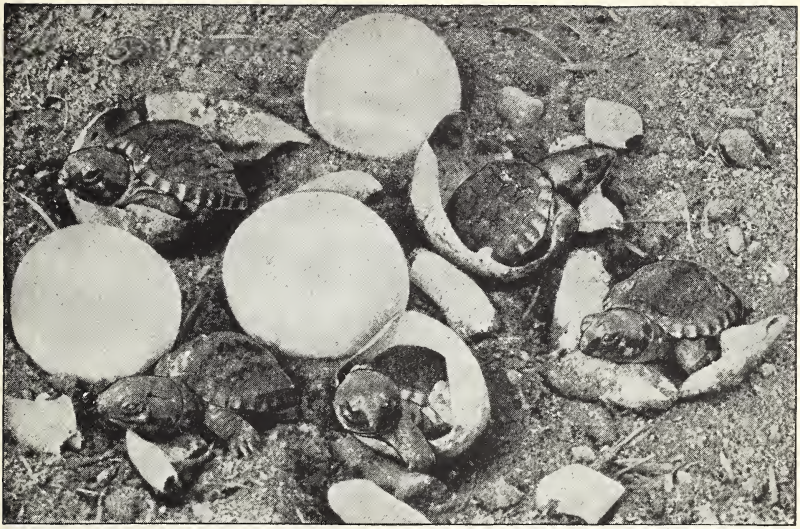
There are many adaptations for protection in this group. Some harmless snakes have protective resemblances. For example, some kinds resemble poisonous forms in color or in markings. Also, others may hiss and strike in a very convincing manner.

Turtles. These are the only reptiles that are protected by a shell. This shell is developed partly from the skin, just as are the scales of other reptiles, and partly from the vertebrae. The head, legs, and tail can be withdrawn under the shell when danger threatens. Some of our land turtles (the box turtles) have shells which are hinged across the middle of the lower plate. These shells can be closed completely with the animal inside. Turtles which live on land have distinct toes ending in claws. Those which spend all their time in the water have the legs modified into flippers for swimming.

The disposition of a turtle seems to be closely related to the amount of shell. The snapping turtle, for example, which has relatively little shell to protect it, is fierce and vicious, while the box turtle can hardly be persuaded to bite.

These reptiles differ greatly in their choice of food. The snapping turtle and soft-shelled turtle feed on fish, frogs, crayfish, and water birds. Land turtles eat much vegetation, as well as many insects and worms.

Lizards. Lizards resemble certain of the amphibians in general appearance; but, unlike the amphibians, they have scales. Unlike the snakes, lizards have movable eyelids and ear openings. Among the lizards familiar in various parts of the United States are the skink, the swift, the chuckwalla, the horned



Lynwood M. Chace

Turtles hatching from eggs. Do you think this "nest" is near a stream or lake or is far from water? Explain

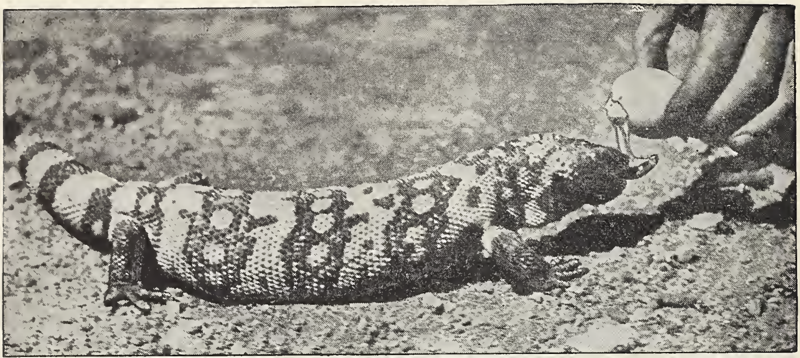
toad, and the Gila (pronounced hē′lȧ) monster. Lizards are feared by many people almost as much as snakes. All are harmless, however, except the Gila monster, which is poisonous and which lives chiefly in the desert regions of the southwestern United States. It seldom attacks man.

In certain parts of our country lizards with no legs are found. These animals move like snakes and closely resemble them in appearance, except that they have ear openings and movable eyelids. The "glass snake," or "joint snake," is such a lizard with a very long tail.

Alligators and crocodiles. Alligators and crocodiles are large reptiles covered with heavy scales. They spend most of their time in the water, with only the eyes and nostrils above the water level. Their powerful tails enable them to swim rapidly. By means of their heavy jaws they catch and eat such animals as ducks and other water fowl, pigs, chickens, and even dogs.

Alligators and crocodiles are much alike, although there are certain differences. The alligator has a broader, shorter snout than the crocodile. Also, its large lower teeth fit into pits in the upper jaw. Those of the crocodile do not.

Alligators are found almost entirely in the Western Hemisphere. Crocodiles are found largely in the fresh waters of Asia and Africa, though one species occurs in Florida and the West Indies.



John Edwin Hogg

A Gila monster. The reptile is too much interested in the food here to be dangerous. **Exercise on Scientific Method (Making Inferences):** What does this picture tell us of the food habits of this animal?

Economic importance of reptiles. In general, man benefits from the feeding habits of reptiles because not only do they destroy few plants and animals of value to him but also they feed upon insects, squirrels, mice, and other animals harmful to crops. Some turtles, as well as a few species of lizards, especially the iguana, are prized for food. From the skins of alligators and crocodiles and certain snakes ornamental leathers are manufactured.

In the United States the death toll from poisonous snakes and the Gila monster is small. In some of the tropical countries, however, thousands of people die every year from snake bites. In India alone, in one year, nearly twenty-two thousand people were killed by snakes, mostly by the krait and the cobra.

Self-test. 1. The *largest* reptiles today are *larger* than the largest reptiles of previous ages.

2. The *dinosaurs* became extinct because they were unable to become adjusted sufficiently to a changing environment.

3. One characteristic of reptiles which marks an important advance over fish and amphibians is the possession of --?-- all of their lives instead of gills for part or all of their lives.

4. The shell of a turtle is a structure which is homologous to the --?-- of a snake.

5. *All* reptiles are hatched from eggs.

6. In general, the snakes of the United States and Canada are more *valuable* than they are *harmful*.

7. A lizard can usually be distinguished from an amphibian by its *skin.*

8. Name the four kinds of poisonous snakes and the one kind of poisonous lizard of the United States.

WHAT ARE SOME ADAPTATIONS OF THE BIRDS[1] WHICH ENABLE THEM TO LIVE SUCCESSFULLY?

Birds related to reptiles. About seventy-five years ago a fossil feather and two fairly complete fossil skeletons of a strange creature were found in the rock of the limestone quarries of Bavaria The creature, which was about the size of a crow, was apparently a bird. Yet it had a number of reptile-like characteristics. It had three claw-like fingers on each wing, sharp cone-shaped teeth rooted in sockets in the strong jaws, a long tapering tail like that of a lizard, and some other reptile-like characteristics. It was, however, covered with feathers and had a number of other bird-like characteristics.

A careful study of these fossils convinced scientists that the creature was a bird rather than a reptile, and also that it was descended from the reptiles of a still earlier period. It is not thought likely, however, that the ancestors of this bird (*Archaeopteryx*) were ancient flying reptiles (the pterodactyls). It seems somewhat more probable that the strange creature was a descendant of certain of the dinosaurs. It is even thought probable that this fossil bird represents the common ancestor of both the modern birds and the modern reptiles, since the birds and the reptiles of today are alike in several ways. Birds, for example, have scale-covered legs and feet, as do lizards and crocodiles. Moreover, most reptiles lay eggs, as do the birds.

Bird characteristics. *Birds are readily distinguished by the fact that they are the only animals that are covered with feathers. Other characteristics may easily be observed.

Experiment 40. 1. What are some of the characteristics of a living bird? You may use any kind of bird for this experiment. A robin or an English sparrow may be watched in your yard or on the school grounds. A chicken, canary, or pigeon may be brought to school or observed at home. What is the shape of the body? Are the feathers which cover the body alike on all parts of the bird? How do you account for this fact? How does the bird use its wings? If you can observe it flying, try to describe the movements of the wings, and to show how these movements keep the bird moving through the air. For what purposes does it use the tail? Look closely at the feet. How many toes are there? Describe their shape and arrangement or make a sketch to show what you observe. Do all birds have feet like this? Look closely at the beak. What shape is it? How does the bird use it in securing its food?

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[1] Phylum Chordata, class Aves.

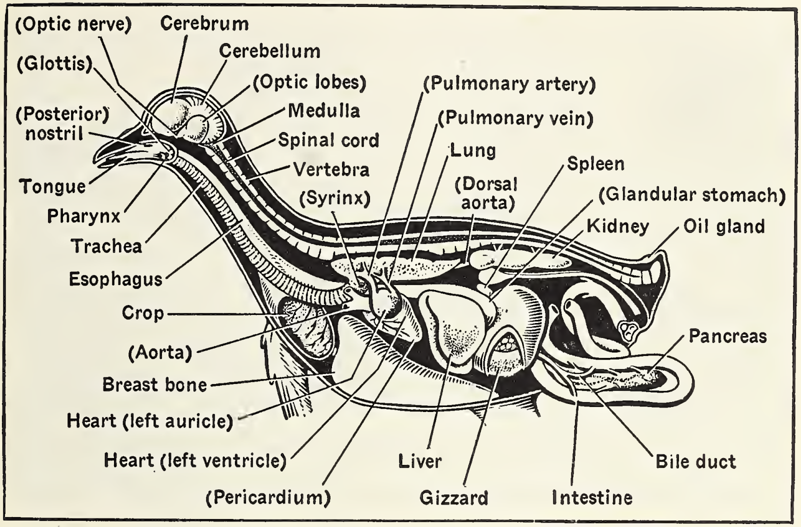
A. M. N. H.

Left, the most ancient known bird (*Archaeopteryx*); right, the hoatzin of the Amazon region. **Special Report:** How do the characteristics and habits of the hoatzin differ from those of our familiar birds?

Watch the bird drink. Make a sketch of the head and beak. Are the eyes large or small as compared with the rest of the head? Do they seem to have the same parts as your eyes? If you can watch a bird closely, look for the third eyelid (nictitating membrane). Where is it attached? Find the nostrils; the ears. Describe the location of these or put them on the sketch you have made of the head.

2. What are the internal structures of a bird? This experiment may be performed by one or more members of the class for the entire group. Carefully dissect a chicken and identify the structures shown in the figure.

Like most other vertebrates, every bird has two pairs of appendages. The anterior pair is modified to serve as wings; the posterior pair are the legs. Different orders of birds vary considerably because of differences in the environments in which they live. Some birds, like the ostrich, have developed the ability to escape from their enemies by running rather than by flying. These have lost the use of their wings, which are now too small and weak to support the body. The wings of the penguin are modified into paddles for swimming.

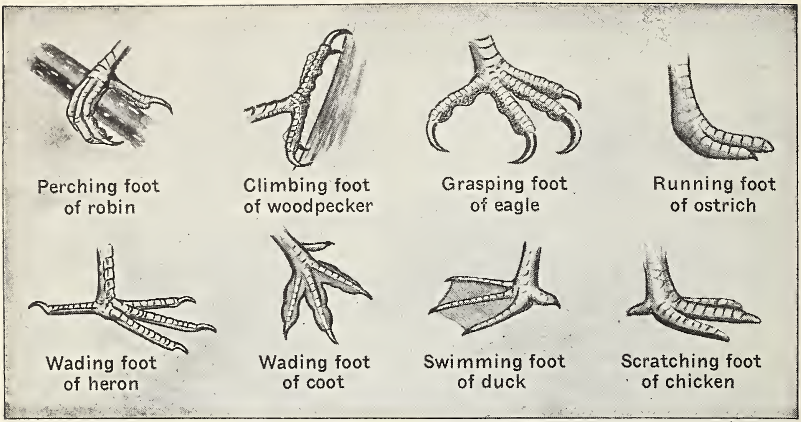


Internal structure of a bird. What internal structures do the bird and the frog (p. 217) have in common?

Special adaptations. Those birds that do much flying need to be especially adapted for aerial life. The body is long and slender and therefore makes little friction with the air during flight. The bones and the quills of the feathers are hollow and filled with air. Moreover, in the abdomen there are air spaces which connect with the lungs. The feathers form a very light, yet a very warm, covering.

The wing is really a modified foreleg, just as is the arm of a man. In fact, the structure of a bird's wing is much like that of a man's arm. The bones which have developed into fingers in man are much reduced in the birds, with the result that the wing is lighter. The wing feathers are long and strong. They lap over one another making a broad surface which is useful in pushing against the air. On the upward stroke the feathers separate slightly and turn to allow the air to pass through, so that the bird does not push itself backward.

Birds that spend most of their time in the air have very long powerful wings. The chimney swift is a bird of this sort. It is said to be able to spend as many as twelve hours continuously on the wing. Ground birds that fly only for short distances have short wings, which they may move very rapidly. Soaring birds, like the hawks, keep aloft with little effort by seeking the



Can you explain how these various adaptations of birds' feet aid the birds in survival?

ascending air currents, which push against their long broad wings. Birds such as swans, geese, chickens, and turkeys use their wings in fighting.

The tail is usually used as a rudder in flight and as a brake for stopping. The wings are partly folded and the tail is spread out when the bird wishes to alight. When the bird perches on a limb, its tail is used as a balance, serving the same purpose as the umbrella carried by a person who performs on a stretched wire in a circus. In such birds as the woodpeckers and creepers the tail feathers end in stiff tips. These can be used to prop the bird on a tree trunk while it works.

Most of our birds have feet fitted for perching on trees or like supports. But different species can also use their feet for walking on the ground, for carrying prey, for fighting, and for various other purposes. Swimming birds have the toes wholly or partly webbed. Wading birds have a long ankle bone, and very long toes which support them in the soft mud. Birds of prey, like the eagle, have long curved claws (talons) to hold their prey.

Usually a bird's foot has three toes in front and one behind. But in many of the woodpeckers there are two in front and two behind to help in climbing and in clinging to the bark of trees. In the birds of prey the outer front toe is readily movable, and can therefore be turned to help the hind toe in holding a victim.

Feeding. We sometimes say that a person has the appetite of a bird, meaning that he eats very little. But if a person truly had the appetite of a bird, he would eat daily approximately his own weight in food. A very young robin eats two or three times its own weight every day.

Lynwood M. Chace

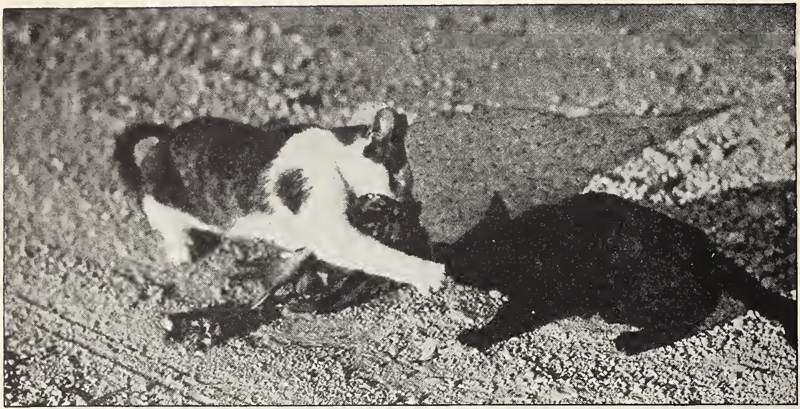
A killdeer on its nest. Self-test on Biological Principles: What biological principle is here illustrated?

Most of a bird's activity is concerned with feeding. From morning to night, except when it is resting sometimes in the hottest part of the day, the bird is constantly in search of food. It requires a great amount of food to supply energy for its rapid flight. Then, too, a bird has a higher body temperature than any other animal (104° F to 110° F). Consequently much of the food energy must be converted into heat energy to maintain this temperature.

It is largely because of their enormous appetites that birds are of such great benefit to man. A later chapter presents further facts concerning the ways in which the activities of birds are of benefit to man.

Migration. The fact that birds possess wings and remarkable power of rapid and long-continued flight has enabled them to live more widely distributed over the world than any other kind of animal except man and probably the insects. If food fails or the climate becomes too severe, they can migrate to a more favorable environment. Some fish, a few insects, and certain mammals also migrate.

The question of why birds migrate is one which scientists cannot answer with any degree of certainty. It is clear that the insect feeders must go in winter to other regions where food is available. But why do they return to



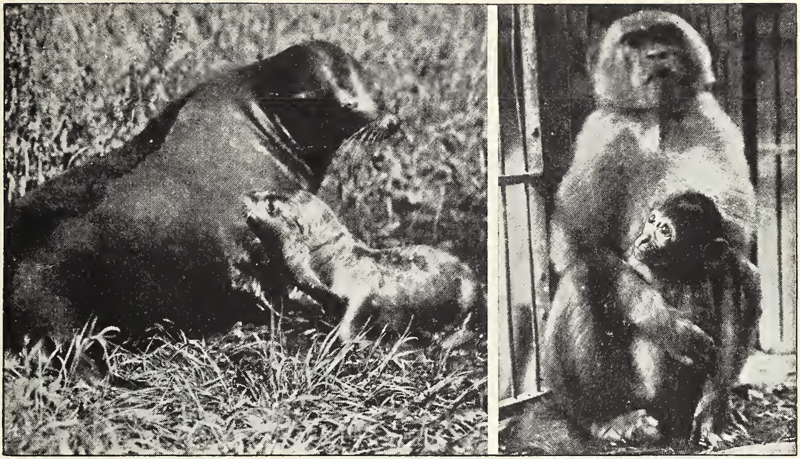
Beecher Beery

Cats fighting over two birds they have caught. Does the cat "pay its way"? Explain. (Courtesy of National Association of Audubon Societies)

us in the spring? Some scientists say that this habit of migration remains from the past ages when great glaciers forced birds to move south to warmer regions, though their tendency was to return north whenever the melting of the glaciers made their return possible. Other scientists think that birds return north because there would not be room for nests and not sufficient food for all if all birds remained throughout the year in the south. Some other scientists believe that the return has some relation to reproduction. They believe that as the season approaches when eggs will be ready to be laid, the birds migrate in search of suitable nesting places.

The birds of any region may be grouped according to their habits in regard to migration. Some, the permanent residents, remain in one locality the year round. Summer residents return for their breeding seasons. Winter residents come to us from colder regions in search of food and a milder climate. Those birds that remain with us for a short time on their way to northern summer homes or southern feeding grounds are called transients.

Bird enemies. Birds have many enemies. Snakes, squirrels, weasels, and many other animals feed upon the eggs and the young birds. Both old and young birds are the prey of other birds, such as hawks and owls. Birds desired as food by man are hunted without pity. Insect parasites of various kinds also cause the death of countless birds and perhaps even the whole species. The common cat, however, is probably the worst enemy of smaller birds. It sometimes hunts and kills as many birds as it can, even when it is well fed. The cat is often of small value compared with that of the birds it kills.



Newton H. Hartman

Left, northern California hair seal and day-old baby (Philadelphia zoo); right, mother monkey and baby. **Special Reports:** Discuss these animals (see "How to Study," **p. ix.** Consult an encyclopedia or an advanced zoology textbook)

Self-test. 1. The ancient ancestors of birds were --?--.

2. The birds are the only animals which are covered with --?--.

3. The bird's wing is similar in structure to the --?-- of a man.

4. State four functions which the feet of birds may serve.

5. Birds need much food energy as a source of both the *mechanical* energy of flight and --?-- energy.

6. Name eight or more bird enemies.

HOW ARE THE HIGHEST ANIMALS[1] EQUIPPED FOR SURVIVAL?

Mammals are comparatively recent animals. A study of fossils found in ancient rocks convinces scientists that mammals appeared upon the earth perhaps one hundred fifty million, or even more, years ago. These earliest mammals, however, were unlike any now living. They were small and unimportant compared with the gigantic reptiles of that time. The mammals developed in size and importance as the Age of Reptiles waned. They have been the most important living things for the past fifty or sixty million years.

Characteristics of mammals. *The mammals are the animals that we know best. Man, dogs, cats, horses, and cows belong to this group. They are called mammals because they have milk glands (mammary glands), which secrete food for the young. Other important characteristics are the following: (1) Their bodies are more or less covered with hair during at least part of their lives. (2) They breathe by lungs all their lives, whether they live on land or in the water. (3) Their young resemble the parents in having the same general structures. (4) They are warm-blooded animals, as are the birds, that is, the body temperature remains the same throughout the winter and summer and is usually considerably above that of the habitat.

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[1] Phylum Chordata, class Mammalia.

The young of all mammals, except those of the lowest order, are born alive. The mammals of the lowest order lay eggs.

Some important orders of mammals. Mammals differ greatly in their habits of life and in their adaptations to environment. The class (Mammalia) is therefore usually divided into sixteen orders, the most important of which are briefly described below and in the figure on the next page. It is not intended that you should try to remember these orders and their characteristics. The outline is intended merely for reference.

THE IMPORTANT ORDERS OF MAMMALS

Egg-laying mammals (Monotremata): duckbill (platypus) and echidna. These are very primitive forms. They hatch their young from eggs, as do birds, but feed the young on milk, as do the higher mammals. They are found only in Australia and neighboring islands.

Pouched mammals (Marsupialia): kangaroo and opossum. The young are very small and undeveloped when born. They continue their growth in the pouch, in which are found the mammary glands.

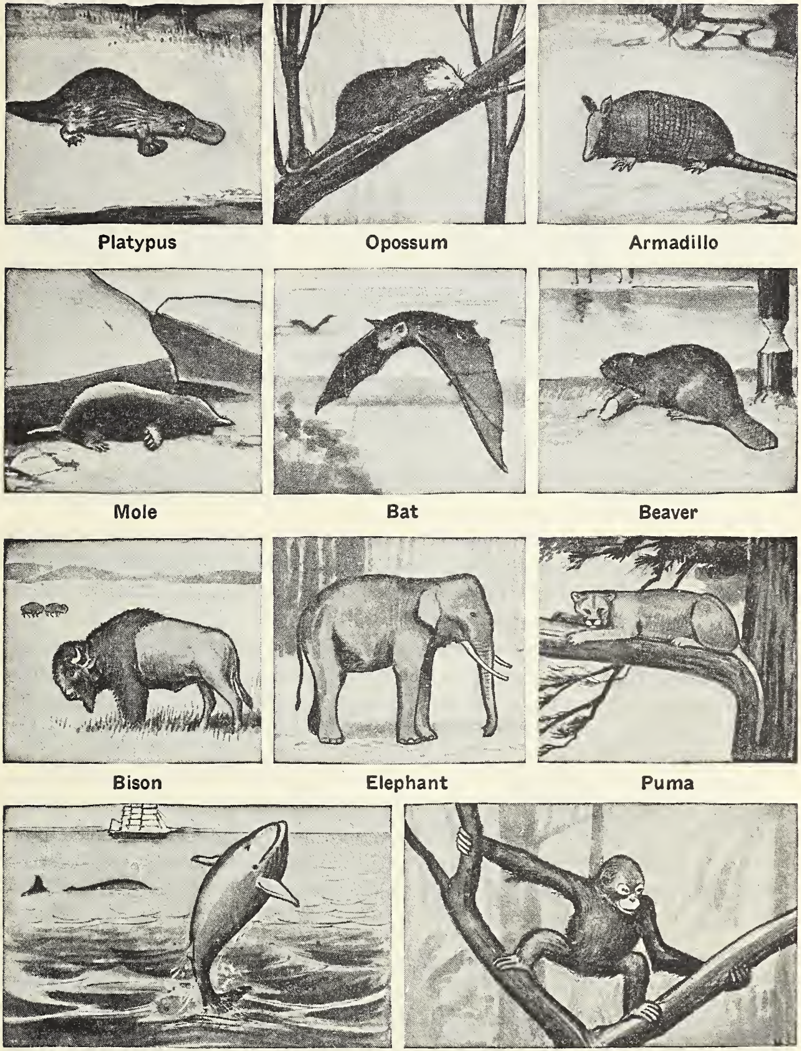
Partly toothless mammals (Edentata): sloth, anteater, and armadillo. These are all slow-moving animals. They feed on insects, worms, and plants. They are found chiefly in the tropics.

Insect-eating mammals (Insectivora): mole and shrew. All the members of this group are small animals adapted for burrowing in the soil.

Flying mammals (Chiroptera): bats. The bones of the front legs are greatly lengthened to support wings of thin tissue. Most bats feed on insects and fruit.

Gnawing mammals (Rodentia): rat, beaver, and squirrel. Some of these animals may do considerable damage in gnawing on buildings, stored crops, and trees. The beaver, muskrat, squirrel, and rabbit are important fur-bearers.

Hoofed mammals (Ungulata): horse, cow, deer, pig, and moose. The teeth are adapted for eating grass and other plants. The legs are specialized for rapid locomotion which helps them to escape the flesh-eating animals that prey on them. They walk on the tips of their toes, which are protected by a modified toenail, the hoof. The horse has one completely developed toe on each foot; the cow, the deer, and the pig have two; the rhinoceros has three. Man has domes-

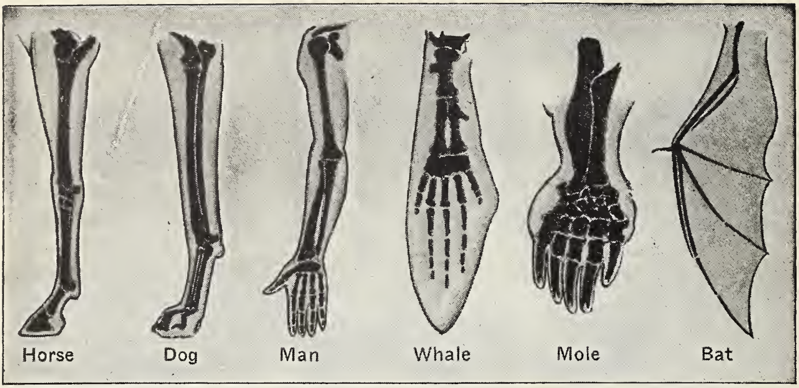

Platypus Opossum Armadillo

Mole Bat Beaver

Bison Elephant Puma

Whale Ape

The orders of mammals. Can you name one or more other mammals in each order represented here? What similar structures do all these animals have?



Modified limbs of mammals. How do you explain the facts that these limbs (1) are so much alike and yet (2) differ in some respects?

ticated many of these animals. The ox, camel, llama, reindeer, and goat are used as beasts of burden in various countries.

Trunk-bearing mammals (Proboscidea): elephant. The trunk is composed of the nose and upper lip, greatly lengthened. These animals were once widely distributed over all the world. Today there are only two species, the African elephant and the Asiatic elephant.

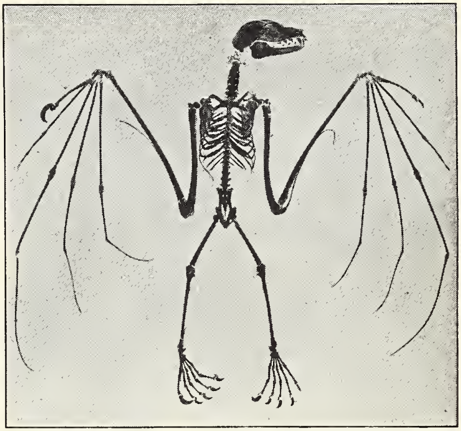
Flesh-eating mammals (Carnivora): dog, cat, lion, seal, and bear. These animals have long sharp teeth adapted to seizing and killing their prey. Of this group of animals, man has been able to domesticate chiefly the dog and the cat. He obtains valuable fur from the fox, wolf, marten, mink, leopard, and seal.

Water-inhabiting mammals (Cetacea): whale, porpoise, and seal. The legs are modified to serve as paddles. Since whales are supported by the water, they have been able to attain greater size than any other animal.

Erect mammals (Primates): man, monkey, and ape. These mammals have more highly developed brains than any other animals. The front limbs of most primates are used for holding and grasping objects.

Adaptations shown by limbs. Most of the mammals possess four limbs of practically equal length. These they use primarily for locomotion, but also for defense and for getting food. There are many interesting modifications of the limbs, and many uses to which the animal puts them. Such animals as squirrels, opossums, and monkeys, which spend much of their time in trees, have feet adapted for climbing. Hoofed animals, like the horse and the deer, have very long slender legs which enable them to attain great speed. The carnivorous, or flesh-eating, animals, as the cat and the lion, have padded feet on which they can approach their victims silently, and claws which can be extended to help in holding their prey. The mole has its front feet greatly enlarged for digging.

In some species the limbs are very different from one another. The very long hind legs of the kangaroo enable it to jump for considerable distances. In the bat the structures of the front limbs differ greatly from those of the hind limbs. Bats are the only mammals that are truly adapted for flying. The legs of aquatic mammals, like the seal and the walrus, are modified in the form of flippers, which are far more effective in swimming than in moving about on the shore.



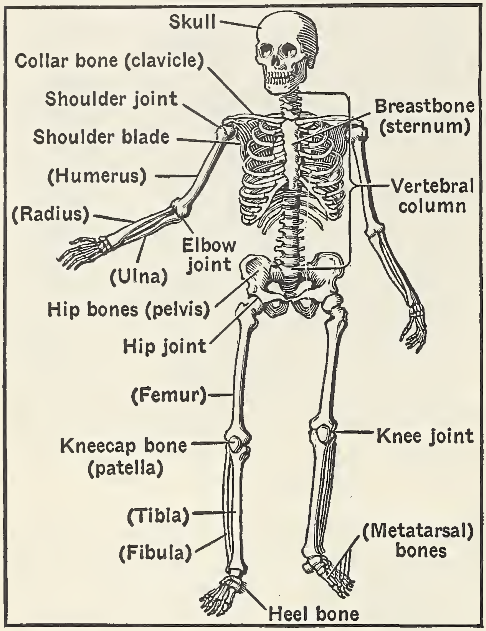
General Biological Supply House

Skeleton of a bat. What structures of the bat are homologous to those of man?

Protection and defense. Many mammals, in their claws, hoofs, teeth, tusks, and horns, have means of active defense against enemies. Others may escape by their speed. The antelope, for example, can run for short distances at the rate of sixty miles an hour. Some animals which have no special organs of defense and no great speed of movement may depend upon their ability to remain concealed. Thus the mole remains safe in its underground burrow.

The skin and the hairy covering of the mammals serve for protection both against attacking enemies and against unfavorable weather conditions. The covering of hair shields the surface of the body from blows or from bites and prevents the escape of too much heat. Most of the animals of cold climates have fur or wool. The hair of the porcupine has become modified in the form of spines, or quills. These spines may pierce the skin around the mouth and nose of an attacker, causing great pain, and perhaps even death as they work their way farther into the body. The whale, walrus, and seal, which live in very cold water, have a layer of fat, or blubber, just beneath the skin, which helps to prevent loss of heat. The armadillo has shell-like bands around its body. When it is attacked, it rolls into a ball and is completely protected.

Protective coloration. Many animals have protective coloration. Thus the color of an animal's coat blends with the surroundings in such a way as to conceal the animal from its enemies or to permit it to creep upon its prey unobserved. For example, a rabbit motionless beside a clod of earth or a clump of grass, or a young deer motionless in the forest, is practically invisible until it moves. Zebras and tigers are difficult to see in their habitats because of their stripes. Polar bears are white like their environment.

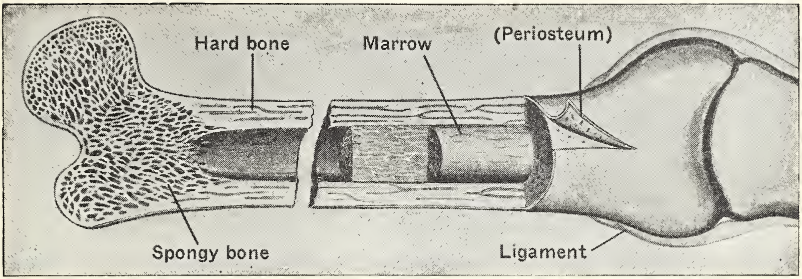


Human skeleton. What examples of the different types of joints can you locate here?

Some animals change color with the seasons. The arctic hare is gray-brown in the summer, but changes to white as the winter snows come.

Other protective adaptations. The severe conditions of winter demand special adaptations for protection. If the body temperature of mammals should be reduced to that of their surroundings, as the temperature of the frog is, they would die. With the coming of cold weather, therefore, many mammals develop heavier coats of fur or wool. Others, if their natural food is lacking in winter, may either hibernate and thus conserve energy or migrate to other locations where food can be found. Many mammals hibernate, but few migrate. The bear hibernates in severe winters when food is hard to get, but may remain active during mild winters. Squirrels and raccoons sleep during the coldest weather. Chipmunks and shrews store food and, during cold weather, wake occasionally to eat.

The bony structure. Since the skeletons of all mammals are very similar, that of man may be studied as typical of the group. The skeleton of man is made up of two hundred six bones. These are of various shapes and structures. There are the long bones, such as those of the arm and the leg, which are hollow and filled with marrow. These bones are the levers which the muscles move to enable us to walk and to lift things. Then there are flat bones, such as those of the skull, the chief function of which is to protect internal organs.



Bone structures. Can you explain the functions of all the structures shown here? (See text)

Bones are living tissue, just as are other softer parts of the body. We have evidence of this fact when we see that a bone grows as an animal increases in size, and that a broken bone can repair itself. Only living cells can perform these functions. A bone is made up of cells, with spaces between them. These spaces become filled with compounds of lime, which make the bone hard. Bones are not entirely solid, but instead are somewhat spongy. A bone has numerous spaces through which blood vessels and nerves can pass to all parts of it.

The bones of the skull fit together in such a way that the joints are immovable. Thus these bones form a box which encloses and protects the brain. In a very young animal the joints of the skull have not closed completely, and therefore room is left for growth. Thus in a baby one finds a "soft spot" on the top of the head. This space is often not entirely closed with bone until the child is two years old.

Other joints in the body are movable ones of three main types. The elbow is an example of a hinge joint. The shoulder is the best illustration of a ball-and-socket joint, which permits movement in any direction. The joint at the wrist is a sliding joint.

Self-test. **1.** Mammals were of *great* importance during the time of the *great* dinosaurs.

2. Name four distinguishing characteristics of mammals.

3. *No* mammals lay eggs.

4. In general, mammals need to produce *fewer* young than animals of other phyla because the young are usually guarded and fed by the parents.

5. The typical mammal has __?__ legs and the typical insect, __?__.

6. Bones consist *entirely* of living cells.

7. Select from the following words and phrases the one which does not belong with the rest: (1) blubber; (2) hair; (3) wool; (4) teeth; (5) claws; (6) bones; (7) quills, or spines; (8) speed.

8. The mammals which are unable to endure cold winters must either __?__ or __?__ in order to survive.

9. Most domestic animals are *carnivorous.*

Self-test on Important Biological Terms

Amphibia
appendage
cartilage
chordate
mammal
reptile
survival value
vertebrate

Self-test on Biological Principles. 1. Explain how the facts about the reproduction of fish illustrate the balance of nature.

2. Cite evidence to illustrate these principles: (1) "To carry on better the functions of higher organisms cells are organized into tissues, tissues into organs, and organs into systems." (2) "When the environment changes, an animal must adjust itself to the change, migrate, or become extinct." (3) "The greater the number of similar parts in an organism, the more simple and primitive is the organism."

Self-test on Organization of Facts. What kinds of skeletons do representative plants and animals from the different phyla have? Can you arrange these different structures in order from simplest to most complex?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. List all the ways you can in which the fish is adapted for moving rapidly. What other adaptations enable fish to escape from enemies?

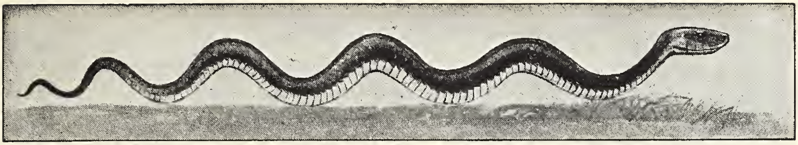
2. Frogs' and toads' eggs are spherical, black on top and white on the bottom. Can you explain why this is a desirable adaptation?

3. How does the metamorphosis of the frog resemble that of the butterfly? How does it differ?

4. Why would a snake have difficulty in moving on a smooth surface, such as a polished table top?

5. If you were to see an animal which you knew must be either a lizard or a salamander, how could you determine which it was? If you were to see an animal which looked like a snake, how could you be sure it was not a lizard with no legs?

6. Can you name two examples of each of the following groups of birds for your own locality: summer residents, winter residents, transients?



Exercise on Scientific Attitudes: Does this picture correctly represent snake locomotion? What scientific attitudes (p. 624) should you need to possess in order to determine whether or not the drawing is correct?

7. How many mammals can you list in three minutes? Examine the list of mammals you made. Group together the ones that seem to be alike in some way. What are some of the facts that you used in making these groups?

Can you place each of the animals on your list in its proper order? (Consult a dictionary or an encyclopedia if you have difficulty.) Which of the orders listed are represented in your vicinity? Which of the orders listed are of most value to man for food? for furs? for beasts of burden? Which of these groups does most damage? How?

8. How are the legs of animals that live in trees modified? For what purposes can a squirrel or raccoon use its front feet? How is a flying squirrel adapted for gliding through the air? What other examples can you think of which show how mammals are fitted for the environment in which they live?

9. If one were to receive a severe blow on the head, what advantages would there be in having the skull constructed as it is rather than of one bone?

10. Compare the shell of a turtle with the exoskeleton of an insect.

11. Can you mention animals other than fish which are for sale in fish markets? To what phylum does each belong? You may need to review Unit III briefly before you can answer this last question.

12. Cite evidence from this chapter to illustrate this generalization: "The world is very old."

Exercises on Scientific Method. 1. *Planning Experiments.* One often hears that handling toads will cause warts on the hands. This belief is, of course, an absurd superstition. Describe all the necessary steps of an experiment which, if performed, would *prove* that toads do not cause warts.

2. *Making Inferences.* If you have been boating or bathing in a lake or along the seashore and have observed the water plants, you have noted that they stretch upward toward the surface in much the same way that land plants stretch their branches and leaves upward. If, however, you have removed these plants from the water, you have found that their stalks were no longer able to hold up their leaves. Similarly, if you were to see a jellyfish on the surface of the ocean, you would observe its tentacles stretching almost straight down from its bell-shaped body. But if the jellyfish were washed upon the beach, you would find that it would lie on the sand in a flat mass. Many organisms, such as the water plants and the jellyfish, which live only in the water, have no supporting structures, though some of the plants become much longer than the tallest trees. Can you explain why they do not need such structures?

Marjorie Shanafelt

Exercise on Scientific Attitudes: There is an old belief that there is a magic jewel in a toad's head. What can you learn about this ancient superstition? Which of the scientific attitudes relate to this old belief?

3. *Making Hypotheses.* What are some reasons which might account for the extinction of the giant sharks?

Exercise on Scientific Attitudes. 1. One often hears it said that if a person finds it necessary to sleep on the ground where there are rattlesnakes, he will be safe if he puts a horsehair rope in a circle around his blankets because a rattlesnake will not crawl over a horsehair rope. From the evidence in the figure on page 221, do you believe this statement to be true? Why? What scientific attitudes (p.624) are here illustrated by this belief and by your decision regarding it?

2. The tails of some of the lizards—for example, the "glass snakes," or "joint snakes," and the swifts—break off readily. When attacked the lizard leaves its wriggling tail to hold the attention of its enemy while it escapes. We sometimes encounter the belief that the animal later returns for the tail, which joins itself to the body again. What scientific attitudes are illustrated by your unwillingness to believe this foolish story?

3. One frequently hears tales of a marvelous "hoop snake," which travels by grasping the end of its tail in its mouth and rolling along like a hoop. As it passes its prey or its enemy, it is supposed to uncoil and thrust into its victim the sharp, poisonous spine on the end of its tail. Of course no such creature ever existed. How many scientific facts can you state which would help to prove that the "hoop snake" could not exist? Which of the scientific attitudes (see list on page 624) are illustrated by your unwillingness to believe in the existence of "hoop snakes"?

Project 16. To study a bird's wing. What is the bony structure of a bird's wing? The wing of a chicken or other large fowl should be used in this project. The wing bones of any bird which has been cooked for the table will serve very well if the wing has not been taken apart. Remove any bits of meat and scrub the bones with soapy water and a small brush. Take care not to lose any of the small bones of the lower part of the wing. When the bones are dry, fasten them in proper order to a piece of cardboard by putting a fine wire or thread through the cardboard and around the bones. Or you may fasten the bones together at the joints with a fine wire or with glue.

Project 17. To trace the migration routes of some of our local birds. Draw or trace an outline map of the Western Hemisphere. Consult Chapman's *Birds of Eastern North America* or a similar book, to learn the migration routes followed by various birds. Put lines on your map to represent the route of each bird you study. Do our migrating birds return to us by the same route they follow south?

Project 18. To secure some frogs' eggs and to watch them develop into frogs. Bring some frogs' or toads' eggs into the laboratory. You will find them in almost any shallow water, about the middle of March or the first of April. Watch their development. Those of the spring peeper, or the tree frog, will prove extremely interesting, since they will complete their development before school is out. Be sure to have water plants and algae in the water to furnish food. A hand lens or reading glass will help in your study of the developing eggs and later the tadpoles.

Project 19. To collect and classify turtles. The common turtles of our inland lakes and streams are the snapping turtle, pond turtle, musk turtle, soft-shelled turtle, and painted turtle. How many of these do you know at sight? Collect as many different kinds as you can find. Consult a reptile "key" or a college zoology for descriptions, and classify the turtles you have found. Do you find others not named above? Did you find any in the woods? After you have classified and studied them, return them to their natural habitats.

Special Reports. 1. What can you find out about the cod and halibut industries of New England and Newfoundland? canning salmon on the Pacific coast and in Alaska? the source and preparation of caviar?

2. How many different kinds of fresh, dried, and canned fish are for sale in your local markets and grocery stores?

3. Do flying fish really fly like birds? What is a lung fish? How is a climbing perch adapted for moving on land? (Consult an encyclopedia or an advanced textbook on zoology or ichthyology (the study of fishes).)

4. How do the Surinam toad and the marsupial frog bring forth their young alive? How does the obstetrical toad take care of the eggs? (Consult a college zoology or an encyclopedia.)

5. What are the characteristics and habits of the alligator and the crocodile? of the chameleon?

6. Where are the poison fangs of the Gila monster, and how does the animal use them in fighting? (Consult a book on reptiles or an encyclopedia.)

7. Who was John James Audubon? For what purposes are Audubon societies established?

8. What mammals other than those named in this chapter hibernate during all or part of the winter? What mammals store food for winter use? What mammals build nests or similar homes? Migration: The fur seal and the reindeer are among mammals that migrate. Find facts concerning their habits. The lemmings of Scandinavia have very unusual habits of migration. Report on this migration.

9. What carnivorous mammals are injurious to domestic animals in some parts of North America?

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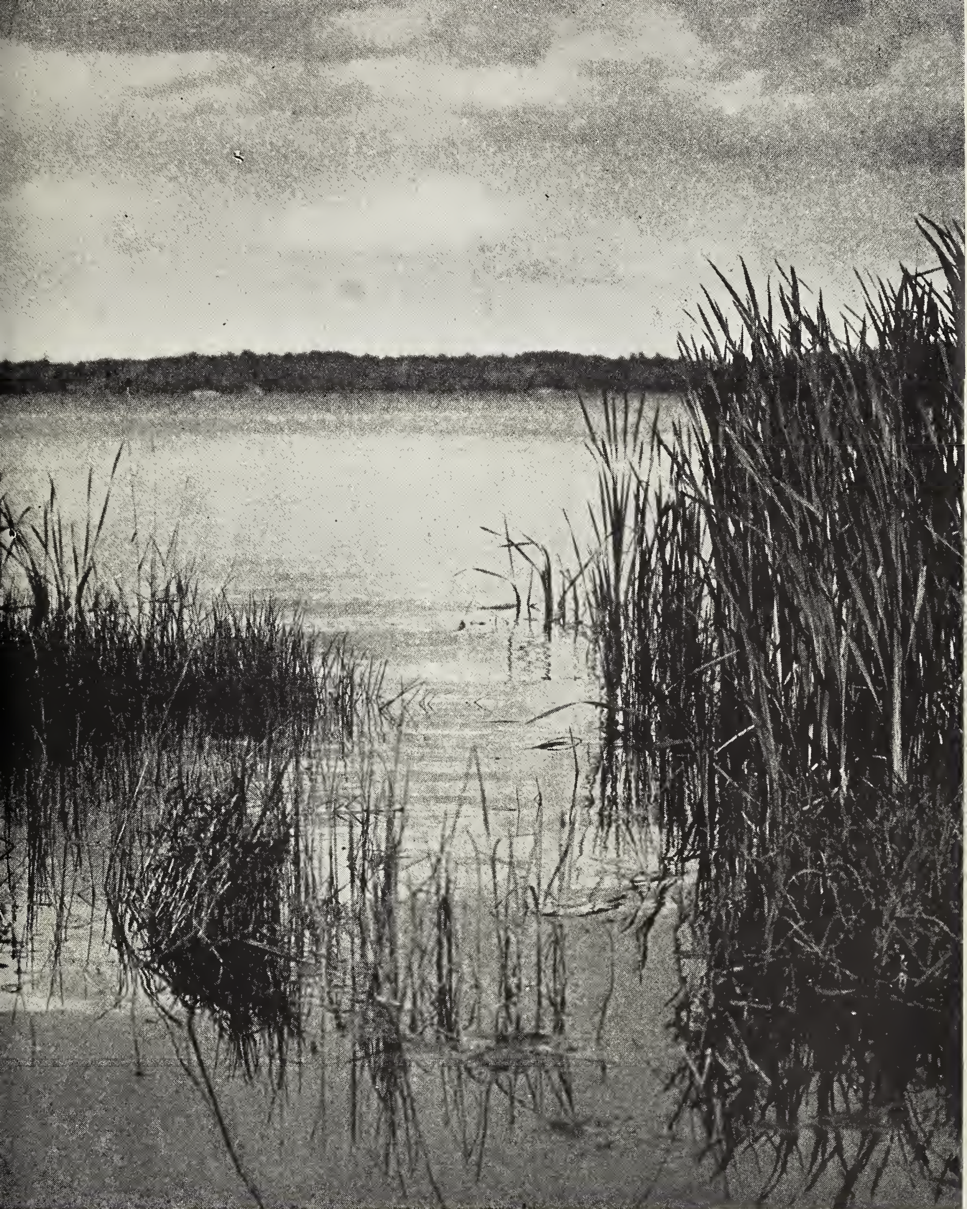
Frogs, Toads, and Salamanders. Eastman Kodak Company, Rochester, New York.

Fungus Plants. Erpi Picture Consultants, New York.

Microscopic Animal Life. Eastman Kodak Company, Rochester, New York.

Pond and Stream Life. Society for Visual Education, Chicago.

The Mosquito. United States Department of Agriculture, Office of Motion Pictures, Washington, D. C.



Armstrong Roberts

Exercise on Scientific Method (Making Inferences). What kinds of plants and animals do you think would be found in such a habitat as this?

UNIT IV · CONSERVATION

Grandmother said, "When I was a little girl, we picked flowers where the county court house now stands." "Yes," said Grandfather, "and that low ground where the forest was is still called 'Deer-Lick Spring' because wild deer used to come there to lick the salty deposits from the old spring. But the flowering plants, the trees, the deer, and many other wild things have been gone for many years."

Statements similar to these could be applied to every part of this country. The early pioneers, pushing westward in their eager search for homes in the vast new territory, found an abundance of natural resources. Wherever they settled, they found fertile grass land or great forests of fine timber.

F LIVING THINGS

Also, they found wild animals and birds in great numbers. When the land had been made ready for planting, the rich soil produced crops in great abundance.

It seemed impossible in those early days that any of the natural resources could ever be exhausted. The contrary has proved to be true. Some of our most valuable and formerly abundant resources have been greatly reduced or have been completely exhausted. We have come to realize that only through wise and careful planning can we hope that the land and the living things it supports will continue to be of use and value to future generations of men.

This unit discusses the conservation of plant and animal life in relation to present and future human welfare.

CHAPTER XIII

Biology and Conservation

Questions This Chapter Answers. 1. What are the sources of soil? · 2. How does the nature of the soil determine the nature of the plants? · 3. What are some important facts about soil bacteria? · 4. How are irrigation and dry farming used in growing crops in dry soils? · 5. What are the important methods of soil conservation? · 6. How does the insect problem affect agriculture? · 7. How does man try to control insect pests? · 8. How does man fight the fungi which compete with him for energy?

HOW DO MEN USE AND CONSERVE SOIL?

Sources of soil. It is now believed by most scientists that there was a time, millions of years ago, when there was no soil. The earth's surface is thought to have been composed at that time of many separate pieces of rock and compounds of metals loosely scattered about. This period was, of course, ages before there were any living things on the earth, and even before there was an atmosphere or water. Without air and water rocks could not change in their composition. They could change in size only by breaking as they were suddenly heated or cooled, or when they were struck by other masses of rock falling upon the earth's surface from beyond the atmosphere, or when they were broken apart by gravity.

During millions of years the earth continued to increase slowly in size as material continued to fall upon it. Finally it was large enough to hold an atmosphere. Only then was it possible for the oxygen in the air and in pores of the rocks to combine with various substances in the rocks and thus to change them into soil. The water, falling as rain and running from higher to lower ground, carried with it the particles which had been broken from larger pieces or had been changed to soil. Thus the rock became exposed to further chemical action from the air. Also, water freezing in cracks in the rock expanded and broke the rock. At the same time erosion[1] produced great changes in the earth's surface.

Slowly, during the course of millions of years, all but the steepest slopes and the tops of mountains became covered with soil. The eroded soil was deposited in lower places by wind, running water, and moving ice. When finally plants and animals appeared on the earth, they also made important changes in the nature of soil. They produced chemical compounds which combined with substances in the soil. Their dead bodies added organic matter. By their various activities plants further broke, added to, and changed the nature of the soil.

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[1] *Erosion* (ē rō'zhŭn): the process of wearing down, or eroding, rock and carrying away rock and soil by the action of wind, flowing water, glaciers, and other agencies.

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An artist's attempt to show how the earth looked before life appeared on it. Which conditions shown here are necessary for life, and which might make life impossible?

Kinds of soil. There are many kinds of soil, depending on the kinds of rocks which decayed or were broken up to produce them and the amount of mixing that has occurred. Soils are usually classified in terms of the size of the particles composing them. These particles range in size from small stones to microscopic particles of clay. Soil may consist largely of stone, gravel, sand, silt, or clay. Mixed with the particles of decayed rock is humus, that is, decaying organic matter. This organic matter is highly important in making the soil fertile.

Experiment 41. Of what is ordinary soil composed? Take a handful of soil and examine it with a strong hand lens. How many different kinds of substances do you find? Does the soil contain humus?

Dependence of plants on soil. If there were no soil, life could not exist on the earth. There could be no plants, and hence there could be no animals. Even fresh-water and ocean plants could not live without the materials which are dissolved from the soil. Land plants depend on the soil (1) for material in which to anchor, (2) for water, and (3) for certain substances needed in building protoplasm and proteins. To be fertile, soil must contain compounds of the elements potassium, calcium, phosphorus, magnesium, sulfur, nitrogen, and iron. Compounds of other elements also are needed for certain plants. These compounds are soluble[1] in the soil water, and therefore they can be taken up by the plant roots by osmosis. The fact that these valuable substances are soluble adds to the danger of their washing away.

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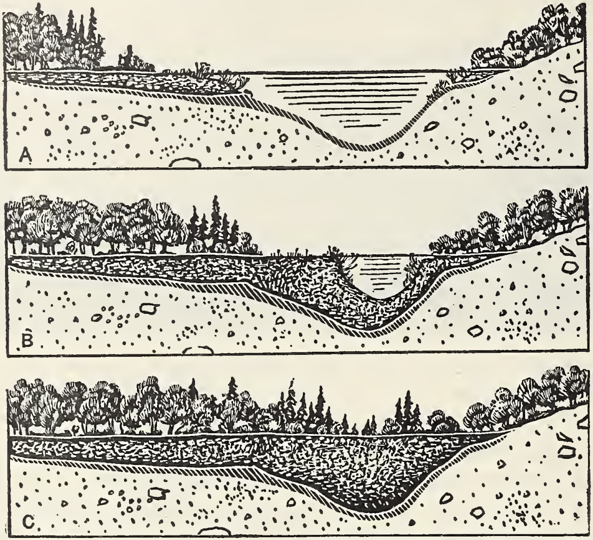
[1] *Soluble* (sŏl'ū bl): able to be dissolved, that is, able to go into solution.



From *Bulletin No. 16*, Geological Survey of Ohio

How new soil is built up in a lake or a swamp. How are plants adding to the soil here?

The nature of the soil determines the kinds of plants which will grow in it. The best soils for agriculture are loams. These consist of various mixtures of sand, clay, and humus. Certain plants, such as the hardy weeds, can grow in a wide variety of soils. Others, such as some of the choicest flowering plants, require very special soils. Certain garden crops, such as onions and celery, thrive best in a heavy soil called muck, which is very rich in humus. Other crops, such as peanuts and sweet potatoes, are better suited to sandy soil.

Poorly drained soil is likely to become acid because the carbon dioxide given off by plant roots dissolves in soil water and forms an acid. If the soil is well drained, the acid may be removed. Certain plants, such as clover, will not thrive in acid soil. Others, such as some of the coarse grasses, grow best in acid soil. Some of the most beautiful flowering plants will grow only in very rich humus. Indeed, modern flower gardening requires most careful study of the kinds of soil that are suited to certain kinds of flowering plants.

Soil bacteria. *Wherever organic matter is decaying in the soil, there are many bacteria. Were it not for the activities of these bacteria, life on the earth would cease. Four kinds of bacteria make the soil more fertile. (1) The bacteria of decay are able to change the dead bodies of plants and animals into ammonia, which is a nitrogen compound, and into other simple compounds. (2) Other soil bacteria are able to change this ammonia into other simple nitrogen compounds. (3) A third kind changes these compounds into other nitrogen compounds (nitrates) that can be used by plants in making proteins for their own uses. (4) Still other bacteria, the nitrogen-fixing bacteria, are able to take free nitrogen from the air in the soil surrounding the roots and to convert it into simple, soluble nitrogen compounds which the plants can use.

The lady's-slipper orchid. This plant will die if taken from its habitat and planted again in ordinary soil. Can you suggest a reason?

Experiment 42. Are there special growths on the roots of clover or alfalfa which are not on the roots of dandelion or lawn grass? Carefully remove several clover or alfalfa plants, together with several dandelion plants or clumps of grass. Wash all the soil from the roots and examine them carefully. In a few sentences or by means of sketches describe the differences.

The nitrogen-fixing bacteria grow within the roots of legumes, or pod-bearing plants, such as beans, peas, clover, and alfalfa. These bacteria gain entrance through the root hairs. They remain in the outer layers of root cells. Here the plant builds thicker walls of cells around the bacteria, thus developing round growths (called nodules, or tubercles). The plant thrives better because of the nitrogen compounds made by these bacteria in its roots. The bacteria profit by being protected within the growths on the plant roots.

The proper kinds of bacteria for producing such growths may be put into the ground at the time when the seed is planted, so as to make sure that the bacteria will enter the plant roots. Sometimes crops of legumes are plowed

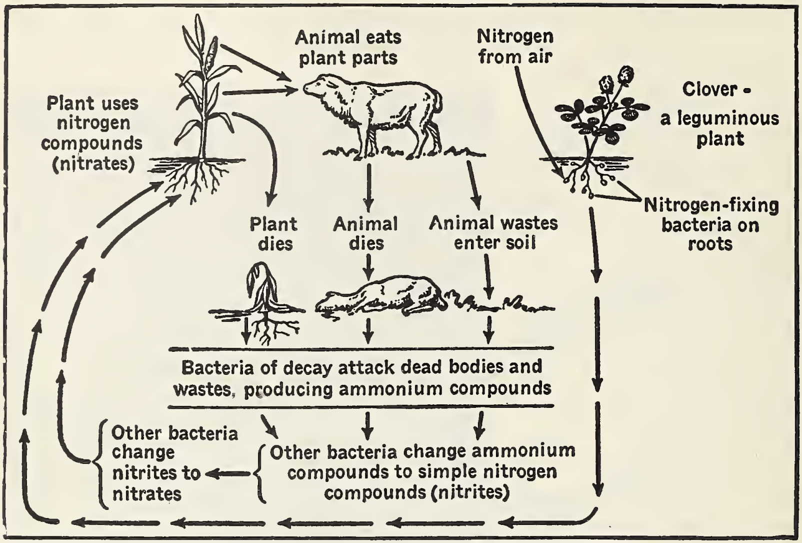

Animal eats plant parts
Nitrogen from air
Plant uses nitrogen compounds (nitrates)
Clover - a leguminous plant
Nitrogen-fixing bacteria on roots
Plant dies
Animal dies
Animal wastes enter soil
Bacteria of decay attack dead bodies and wastes, producing ammonium compounds
Other bacteria change nitrites to nitrates
Other bacteria change ammonium compounds to simple nitrogen compounds (nitrites)

Diagram of the nitrogen cycle. Can you explain this diagram? (Consult text)

under to enrich the soil. Thus, as they decay, they form humus and also free the nitrogen compounds produced by the bacteria. But even when such crops are harvested, their roots enrich the soil.

When grain crops and legumes are grown in successive years, the process is called rotation of crops. Other kinds of crops are also used in crop rotation. The purpose of crop rotation is to keep the soil fertile.

The nitrogen cycle. Each of the four types of bacteria described in the preceding paragraphs has an important relation to the nitrogen cycle. The *nitrogen cycle* involves (1) the use of nitrogen compounds by plants to manufacture proteins and to build protoplasm; (2) the decay of proteins in dead plant and animal bodies, releasing nitrogen compounds to the soil and free nitrogen to the air; (3) the changing, by bacterial action, of these compounds to nitrates or of the free nitrogen to compounds, which the plant can use to make proteins.

Irrigation and dry farming. Many desert regions have fertile soils. A sufficient water supply is the factor needed in order to make these soils produce abundant crops of cultivated plants. Many of the desert regions of the West have been made productive crop lands through irrigation. In recent years many huge dams have been built to secure the water necessary for extensive irrigation projects.

In some regions farm crops can be produced at less expense by dry farming than by irrigation. Dry farming is based on the fact that if the surface soil is kept in a fine, loose condition very little water will evaporate from it. Accordingly the ground is cultivated after every rain to keep it in condition (1) so that it will absorb water and (2) so that evaporation of water from its lower layers will be prevented. Thus a sufficient quantity of water may be stored in the soil to make possible the production of a crop every other year.

Modern agricultural problems. Modern scientific agriculture has developed to such an extent that abundant food can now be produced. Clearing and draining new lands, reclaiming desert lands for use in irrigation and dry-farming projects, continued farming of older agricultural areas, and applications of scientific farming now make possible the production of a surplus of food. How to dispose of this surplus to the advantage of the farmer and so that everybody may have all the food he needs is an important and difficult problem.

How to protect from erosion the agricultural land we now have is an equally important and difficult problem.

Erosion of agricultural land. Erosion has destroyed an appallingly large area of agricultural land in this country. As a result of erosion about fifty million acres which formerly produced food crops can no longer be cultivated. Also, as a result of erosion another fifty million acres are rapidly approaching the worthless condition of the first fifty million. Distributed over ten of the Middle-Western and Southwestern states are several hundred million acres which should never have been plowed, for the reason that, when plowed, such land erodes so rapidly that it soon becomes useless for agriculture.

The great corn belt of the Middle West has always been very fertile land. That an important part of this soil could ever be lost was not suspected. But recent investigation indicates that erosion has already removed an amazingly large amount of it. Before farming on a large scale was begun in this region, a railroad bought land on which to lay its tracks. This land is therefore the original soil. Recently an expert on soil conservation[1] decided to compare the depth of the original soil with that of the soil in the farms next to the railroad. He found that along the tracks, where the soil had not been disturbed, there were seventeen inches of black soil, while in the field thirty feet away there were only nine inches of black soil. These observations show that in a little more than a century, a layer of good soil eight inches deep has been removed by erosion from the region examined.

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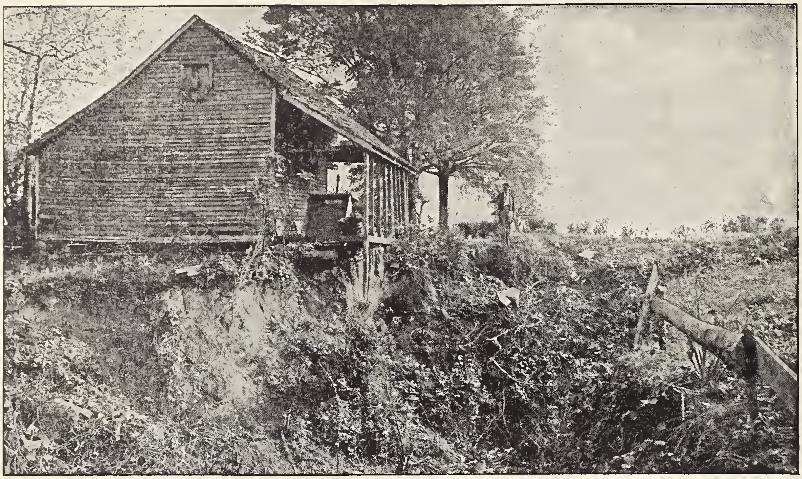
[1] *Conserve* (cŏn sẽrv′): to preserve from decay, loss, waste, or harm. *Conservation* (cŏn-sẽr vā′shŭn): act or process of conserving.



United States Department of Agriculture, Soil Conservation Service

Can you explain what was happening when this picture was taken and why it was happening?

Erosion by water. Whenever it rains, the water which runs off the ground carries with it small particles of soil. It is only when the ground is covered with a mat of plant roots that this loss of soil is controlled. The rich land of much of our farming areas is now being washed to the sea faster than the natural soil-making forces can produce more soil. Every year, moreover, running water is taking from the soil, in solution, more of the necessary food materials and minerals than do growing crops.

Running water is chiefly responsible for sheet erosion, such as that just described as taking place in the Middle West. Sheet erosion gradually removes the top soil. It occurs on all gently sloping land. It is more rapid, of course, when the soil has been loosened by plowing and when grazing animals have removed too much of the plant life which covers the ground. Sheet erosion goes on so slowly that it is often not easily observed, although it is the most important agent in the destruction of soil.

In regions where the land is sloping or hilly, water may run off rapidly enough to wash deep channels, called gullies. We may see small gullies being formed after a hard rain along a road or in a field. Every time water runs through the gully, the water cuts deeper into the soil. Then the banks begin to cave in, and the gully becomes wider as well as deeper. Some farms have been entirely ruined by gullies. A gully that started in a barnyard about fifty years ago is now in places two hundred feet deep. Where this gully now is there were formerly three thousand acres of good farm land.

Wind erosion. The great dust storms of recent years in the states of Colorado, Nebraska, Texas, and the Dakotas have made us realize, as never before, that loose dry soil is easily carried away. When the top, fertile layers have once been removed, many years must pass before the remaining soil can again become fit to support crops. This land was originally covered with grass, which formed a cover for the soil and a mat of roots to hold the soil in place. When the land was plowed and converted into vast wheat fields, the soil was exposed to the wind. As crop land the ground was bare during part of the year. Several years of insufficient rainfall left the soil dry and loose. It therefore was easily blown away.

One investigator has estimated that the big dust storm of May, 1934, moved three hundred million tons of soil. In this storm, dust from Kansas and the Dakotas was carried entirely across the eastern part of the United States, and was even observed by ships two hundred miles out in the Atlantic Ocean.

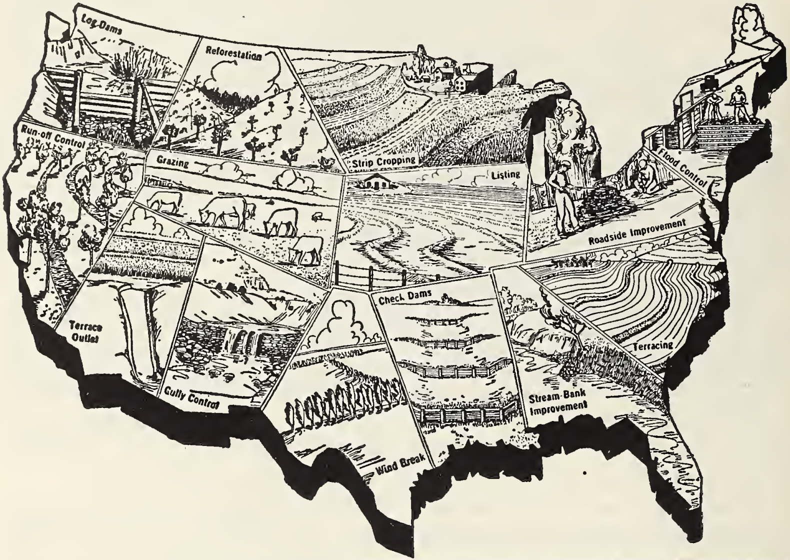
Wind as an agent of erosion does not do nearly so much damage as water. Yet the fact that dust storms are so startling has served one good purpose: it has made everyone realize that there is need for conserving our soil.

Preventing erosion. *The methods which are used in checking erosion are not new. Many of them have been used since ancient times. Most of the European countries have used such measures of conservation for many years. These methods of soil conservation to prevent erosion include (1) planting grass crops and other low plants to keep the soil covered, (2) contour plowing, (3) terracing, (4) strip cropping, (5) planting trees and shrubs, and (6) controlling gullies. Two or more of these methods may be used at the same time.

In regions where sheet erosion has begun but has not yet removed much of the soil, several of these methods may help to hold the soil and to keep it fertile. Contour plowing,—that is, plowing furrows around a hillside rather than up and down it,—will help to keep rainfall from running off rapidly. Moreover, land which has been plowed in this way holds moisture to a depth of one foot more than land plowed in the ordinary way.

Strip cropping consists in planting crops that mature at different times in strips around a slope. Strip cropping ensures that there will never be large areas entirely bare of plants that will hold the moisture.

In regions where erosion by wind or water has seriously injured the soil, the best practice seems to be to plant grass crops and to leave the soil without plowing for a number of years. A certain farm in South Dakota provides a good illustration of the value of this practice. Until a few years ago this farm produced excellent corn crops. But since only corn was grown on it, there were many months of the year when the ground was practically bare. The soil, therefore, became more and more dry, and the corn did not yield so well.

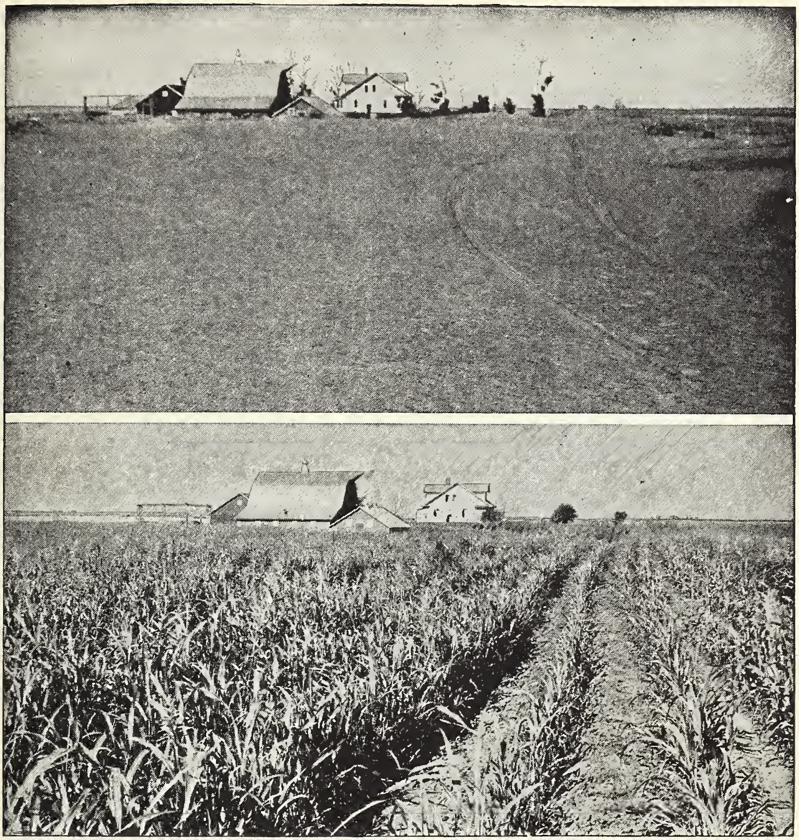


United States Department of Agriculture, Soil Conservation Service

Methods used in reducing the amount of erosion in various parts of the United States. Can you explain how each of these methods makes the erosion less rapid and extensive?

The last good crop was produced in 1927. Then several years of little rainfall made conditions even worse. The soil began to drift and to blow away. The farm finally looked like a desert, and was at last abandoned.

In 1935 the farm was taken over by the Soil Conservation Service as part of a project in demonstrating methods of reclaiming such areas. Grass crops were first planted, not to be harvested but to be plowed under to help to make the soil fertile. After two years of such treatment, the farm was in 1938 again ready to produce crops. But it will not again be planted as one great corn field. Instead it will be divided into small fields. Each of these will be planted with Sudan grass, alfalfa, oats, rye, crested wheat grass, or sweet clover. Also, occasional rows of Russian olive trees will be planted to break the wind. The crops on many of these small fields will not be harvested but will be plowed under to put humus back into the soil. In the future, crop rotation and the use of a variety of crops will be practiced on this reclaimed farm to keep the soil in good condition.



United States Department of Agriculture, Soil Conservation Service

Reclaiming a "dust-bowl" farm. Can you explain how the farm became ruined and how the land is being restored so that it will again produce good crops?

In those regions where gullies form easily, the problem of holding the soil is a very difficult one. As a means of preventing the formation of gullies, it has proved most effective to plant trees and shrubs on the tops of hills and on the steepest slopes. Other slopes are covered with grass or with lespedeza, a small, leafy, clover-like plant which covers the ground closely.

In the gullies themselves, other measures are taken. Sometimes a dam is built to slow down the current of the water which washes through the gully. Thus the amount of erosion is made less. Great success in stopping the rapid erosion in gullies has followed the planting of a vine called kudzu. It grows rapidly and forms a close mat over the soil. Kudzu is a member of the legume family, and is native to Japan. It not only is proving valuable in preventing erosion, but it also is a good crop plant for poor land, since it makes excellent pasture for farm animals.

The Soil Conservation Service, which is a branch of the United States Department of Agriculture, was established in 1934. It is concerned with discovering the best methods for preventing erosion in various types of land and with aiding land-owners to learn and use the best means of soil conservation. It has established, in different sections of the country, one hundred fifty experiment stations, which are intended to discover and to show the best methods of checking soil erosion.

Self-test. **1.** In the earliest ages of the earth the surface was covered with *fertile* soil.

2. If the earth had never had an atmosphere, it could have had *little* soil.

3. Soil is constantly being carried from the *valleys* to the *hills.*

4. Name six methods of controlling soil erosion.

5. There would be *few* fish in the oceans if there had never been any soil on the earth.

6. State what useful service is performed by each of four kinds of soil bacteria.

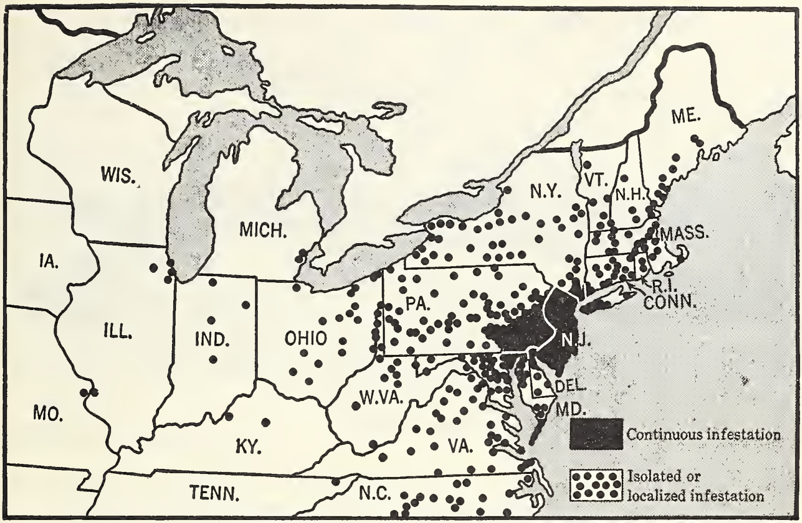
7. The practice of planting alfalfa in a field one year and wheat the next is an example of --?--.

8. Some desert regions have been made to produce good crops by dry farming and --?--.

HOW DOES MAN PROTECT HIS CROPS AGAINST INSECT PESTS?

Agricultural production and the insect problem. Insects are among man's most troublesome enemies. (1) They attack growing crops of grain, vegetables, and fruit; (2) they feed on stored products; (3) they may produce disease directly in domestic animals or indirectly by carrying disease germs from one animal to another; (4) they attack orchard and forest trees; and (5) in other ways they injure men directly or indirectly.

The annual loss due to insect pests in the United States amounts to over a billion and a half dollars. Plants are the natural food of many kinds of insects. Moreover, agricultural plants seem to be preferred by many insects for food. Consequently it is estimated that insects destroy one tenth of all the farm crops. Many of us who live in cities may think that the activities of insects do not concern us. Yet they concern city dwellers in many important ways, as will be explained later.



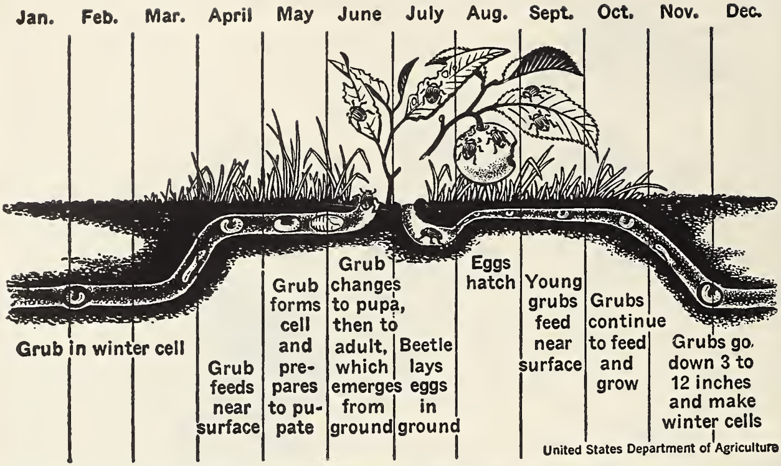
United States Department of Agriculture, Bureau of Entomology and Plant Quarantine

The spread of the Japanese beetle. Does this map indicate that the balance of nature has been restored with respect to this pest? Explain

It is in their feeding activities that insects do their chief damage to our crops. The varied food habits of different species of pests enable them to attack plants in all stages of growth and in all their parts. The corn plant just coming through the ground may be cut off by a cutworm. Its roots and leaves may be eaten by plant lice. As it attains greater size, grasshoppers may feed on its leaves and may even destroy it entirely. The plant may fall prey to the European corn-borer or to one of the various corn-ear worms, with the result that it is rendered wholly unfit for our use.

Corn, wheat, and other grain crops are also subject to attack by such insects as the chinch bug, the Hessian fly, the army worm, and many others.

Methods of control of insects that attack crops. *In order to control insect pests man must learn much about their habits: (1) He must discover facts concerning their life histories in order that he may know at what stage the insects can most easily be reached and killed. He must learn about each insect as a special problem, since the life histories of insects vary so widely. For example, many of our insects pass the winter in the egg stage. With other insects the eggs hatch in a few days. (2) Man must understand the feeding habits. When he knows what the insects eat and how they eat, he has gained an important biological key to the problem of control. (3) Man must learn


Jan.
Feb.
Mar.
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Grub in winter cell
Grub feeds near surface
Grub forms cell and prepares to pupate
Grub changes to pupa, then to adult, which emerges from ground
Beetle lays eggs in ground
Eggs hatch
Young grubs feed near surface
Grubs continue to feed and grow
Grubs go down 3 to 12 inches and make winter cells

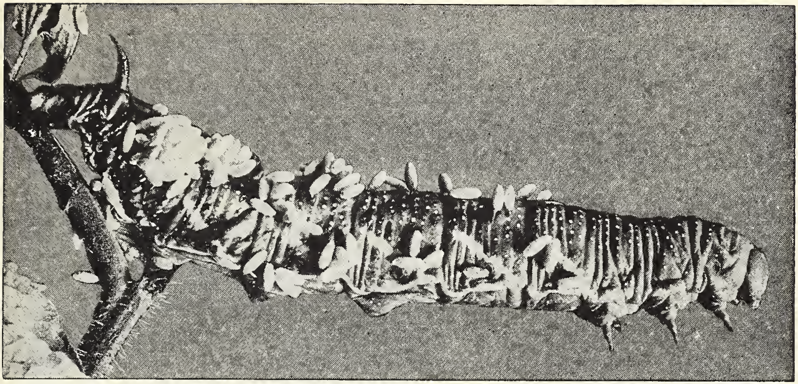
United States Department of Agriculture

Life history of the Japanese beetle. Does this insect have a complete or an incomplete metamorphosis? (Consult Index for earlier references to metamorphosis)

what other organisms are enemies of insect pests, in order to increase the number of these enemies. After he has gained this knowledge of the pests, man can usually employ effectively one or more of the following methods of reducing the insect population:

1. *Using poisons.* The chief means of combating many insects is the use of poisons. An insect which, like the potato beetle, eats the leaves of a plant may be killed by spraying the plant with a poison such as Paris green or arsenate of lead. But an insect like the squash bug, which gets its food by sucking the juices from the plant, would not be injured by poison on the leaves. Such an insect must be killed by contact poisons, that is, by poisons which either attack and penetrate the surface of the body or fill up the breathing pores. Among the commonest of such poisons are those containing nicotine, whale oil or fish oil, soap, kerosene, and sulfur mixtures.

2. *Rotating crops.* Rotation of crops is an important means of controlling pests that feed on only one kind of crop. The larvae of the Western corn rootworm, for example, will eat only the roots of the corn plant. If fields infested with that pest are planted with wheat, oats, or clover, the rootworm may be starved. A similar method of control is applied in fighting the cotton-boll weevil. Since this insect feeds on the cotton plant only, the numbers of the pest can be reduced if no cotton is grown in the infested area for two or three years. The practice in some localities of growing crops other than cotton on land infested with the weevil has already proved of value in controlling the pest.



Cornelia Clarke

A tomato worm infested with the cocoons of an insect parasite. **Exercise on Scientific Method (Making Inferences):** What should you infer the life history of this parasite to be?

3. *Burning or plowing under.* Burning or plowing under the plant parts which remain after the harvest aids in control of some insects. The chinch bug may spend the winter in the stubble of the old plants, and the corn-borer in the cornstalks. Burning over infested fields will reduce the numbers of the insects that appear the following year. Both these insects, however, as well as many other pests, may live through the winter in weeds or grass near the fields or in brush piles. The farmer must clean up all such possible hiding places as well as the field itself.

4. *Using knowledge of life histories.* A knowledge of the approximate time of year when the insect may be expected to feed on the plant is essential to proper control. Thus some food crops are planted early and others late in order to avoid the time when certain pests would be in the stages in their metamorphoses in which they would feed on these plants. For example, winter wheat planted late in the autumn is usually free from attack by the Hessian fly because the Hessian fly usually deposits its eggs before the time of heavy frosts. Also, corn planted in the late spring is less liable to attack by the corn-borer. A third example of crop-timing is furnished by the apple industry. The time when spraying of apple trees is most effective in destroying the codling moth is just after the petals have fallen, for it is at that time that the moths lay their eggs. Therefore the larvae may be killed by the poison before they get into the young apples.

5. *Encouraging enemies.* The natural enemies of insect pests help to keep them under control. The most important of these natural enemies are probably the birds. A very great number of kinds of birds eat insects and insect

larvae. Moreover, they carry large numbers of these insects to their hungry offspring. They usually start their feeding activities before sunrise and stop at late twilight.

Important animal enemies of insects other than birds include frogs, toads, skunks, snakes, and other insects. Thus ladybugs, or ladybird beetles, eat plant lice, scale insects, and the larvae of such insects as the potato beetle. The ichneumon flies lay eggs in the egg masses of many other insects or in the bodies of many kinds of larvae, chiefly caterpillars. The ichneumon fly larvae eat the egg masses or, as parasites, feed on their hosts, the caterpillar larvae.

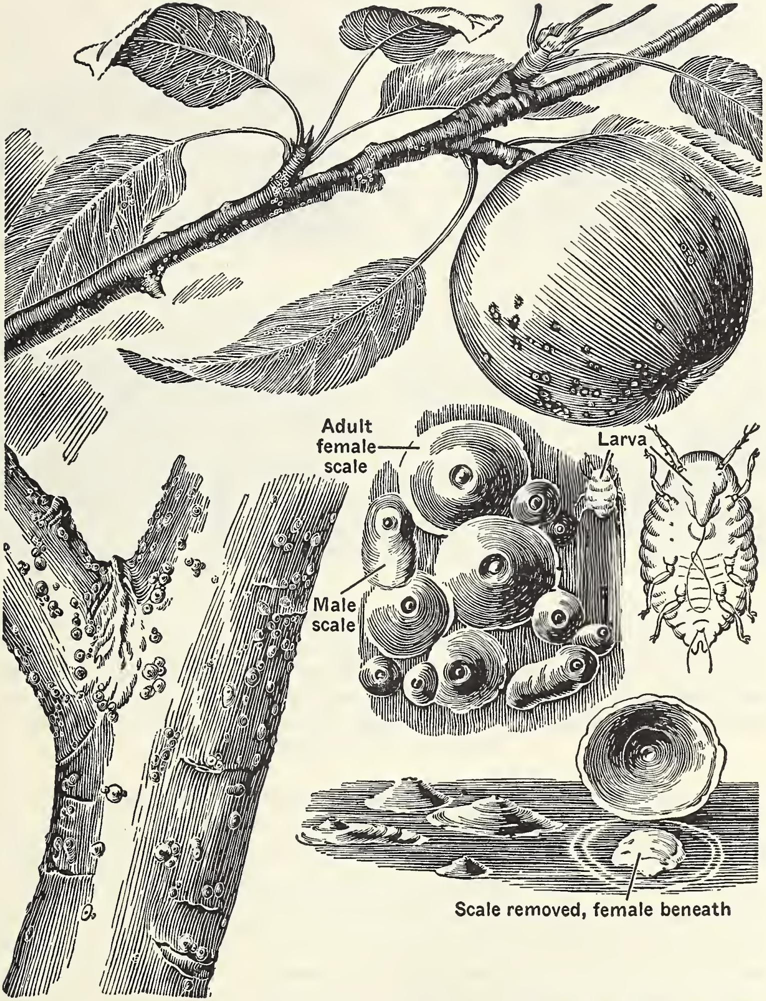
Many of our worst pests are insects that were imported to this country while their natural enemies were left behind. Scientists are engaged in trying to discover and import these enemies, so that they may help to hold our pests in check. In some cases, these efforts have proved successful. The cottony-cushion scale, for example, threatened to destroy the orange trees of California. A diligent search for natural enemies of the scale resulted in the discovery in Australia of a species of ladybug that feeds on this scale. So successful was the introduction of this insect into California that that particular kind of scale is no longer dangerous. Studies are now in progress to learn the natural enemies of some of our most rapidly spreading pests: the Japanese beetle, the Mexican bean beetle, and the corn-borer. It has recently been discovered that one of the roundworms is effective as a parasite of the Japanese beetle.

Besides the insects and other animals which prey upon harmful insects, many kinds of fungi have been found which are parasites of these pests. It is possible, moreover, to plant the fungus in the body of a captured insect and then to release it so that it may spread the disease to others of its kind.

Success in warfare against insect pests. Most of the insects considered are not under control and probably may never be entirely so. All man's efforts serve only to reduce the numbers of the pests. One major victory, however, is even more complete than that over the cottony-cushion scale. This is the conquest of the Mediterranean fruit fly, which first appeared in Florida in April, 1929.

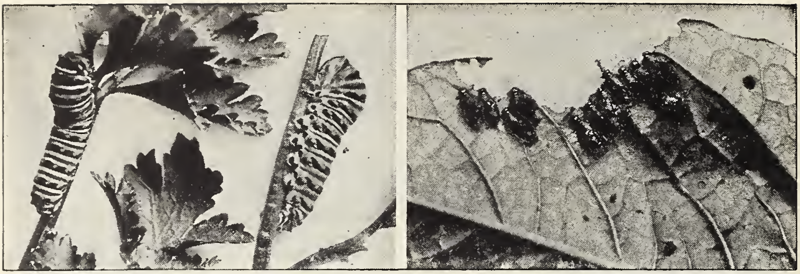
The fruit-fly larva was discovered first in grapefruit. It was soon learned, however, that most fruits and many vegetables, such as tomatoes, eggplant, peppers, and beans, were also infested. All that part of Florida in which the fruit fly was found was quarantined.[1] No shipment of the host fruits or vegetables was permitted from the region. All infested places were thoroughly cleaned. All fruits and vegetables that might contain larvae were destroyed.

[1] *Quarantine* (kwŏr'ăn tēn): a period during which plants, animals, or people having a disease which others might contract, are isolated, that is, are kept away, from others until danger of spread of the disease has passed.

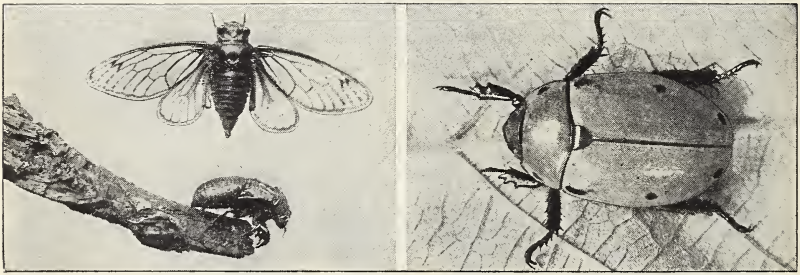


United States Bureau of Entomology

The San Jose scale. Special Report: Discuss the San Jose scale. (See "How to Study," p. x)



Black swallowtail butterfly larvae **Cucumber beetle larvae**



Cornelia Clarke

Cicada **Beetle (Pelidnota punctata)**

Four important insect pests. The black swallowtail butterfly and the cucumber beetle larvae injure plants by eating their leaves. The cicada damages trees by shredding the twigs in order to lay its eggs within them. (This cicada has just molted; the old case is left on the twig.) The beetle (*Pelidnota punctata*), in both its larval and its adult stage, feeds on the leaves of the grape. **Special Report:** Consult an insect book for the life history of each of these insect pests

In order to reduce the number of places in which the insects might lay their eggs, a law was passed prohibiting further planting of crops which the flies might infest. Then, since it was known that the adult fly may live as long as ten months, measures were taken to kill off adult flies. Poison spray was placed on trees along roadsides and orchards. Traps were set in places where it seemed likely that the flies might collect. When the pest seemed somewhat under control, the quarantine was lifted to permit the shipping of fruit which had been heated or cooled enough to kill any larvae that might be present. By November, 1930, so few of the pests were found in fruit examined, and by that time control measures had been so well organized, that it was felt that there was little danger of the fruit fly's spreading to other regions. The quarantine was therefore removed.

This brief summary of the methods used in controlling one pest that might have spread throughout the South and West shows what can be done when there is prompt and effective action by government authorities and the fruitgrowers. The damage done by the gypsy moth (colored plate facing p. 196) is an example of what may happen when insect pests are accidentally introduced and are not controlled.

Summary of methods of controlling insect pests. *Man attempts to destroy those insects which are successfully competing with him for available food energy by (1) spraying the trees and plants with poisonous substances which will kill the insects that eat the leaves; (2) dusting or spraying the plants which he wishes to protect, with substances which will either injure the bodies of the insects or fill their breathing pores; (3) starving the insect pests through planting in the infested land a crop plant which the troublesome insects do not eat; (4) destroying the insects by burning over the infested land or by plowing the infested surface; (5) planting early or late in order to avoid certain insect pests; (6) directing the attack against the pest at the stage of its metamorphosis when the attack will prove most effective; (7) protecting and conserving the birds and other animals which feed upon insect pests; (8) importing and raising insect enemies; (9) inoculating certain pests with parasitic fungi and then releasing the infected insects to spread the disease among their kind; and (10) quarantining infested regions.

Self-test. 1. The problem of insect pests is of *small* importance in *cities.*

2. State five or more methods which are used in controlling insect pests.

3. Select from the following the insect which does not belong with the rest: (1) ladybird beetle; (2) Japanese beetle; (3) corn-borer; (4) pink bollworm; (5) cotton-boll weevil; (6) gypsy moth; (7) Hessian fly; (8) San Jose scale; (9) grasshopper; (10) cottony-cushion scale.

4. Thus far man has won *many* complete *victories* over insect pests.

HOW CAN MAN CONTROL PESTS THAT ATTACK DOMESTIC ANIMALS?

Pests that affect domestic animals. Lice, mites, fleas, and many kinds of flies attack domestic animals by biting them and sucking their blood. These insects may also carry germs of diseases. One kind of tick is known to carry Texas cattle fever. Another carries the germ of Rocky Mountain spotted fever. Among the troublesome flies which injure horses and cattle is the botfly. This fly lays its eggs on hairs, usually on its victim's legs. The horse or cow takes these eggs into its mouth while licking itself to remove the annoyance caused by the presence of the eggs in the hairs. The larvae develop in the stomach, often in enormous numbers. Since these larvae feed as parasites, they do serious injury to the stomach walls of the host.

Another fly which may often be a troublesome pest is the warble fly, or ox warble. It develops as a larva under the skin of a cow. When it is ready to form a pupa, it bores through the skin and drops to the ground. Not only does this pest cause severe pain to the cow during the time that it lives under the cow's skin, but also it is responsible for considerable economic loss because of the damage it does to the hides.

Insect pests do damage of various sorts. (1) They sometimes kill domestic animals. For example, lice sometimes kill not only chicks but also mature fowls. (2) The pests may so torment the young animals that they do not develop normally. Thus young chickens infested with lice are robbed of too much energy to permit their proper development. (3) The pests may cause an animal to lose flesh. (4) They may so weaken the animal as to make it an easier prey to disease germs. (5) They may so annoy or weaken the animal that it cannot produce the normal amount of the product desired. For example, a cow annoyed by biting flies will produce less than her normal quantity of milk. Also, a hen infested with lice will produce fewer than her normal number of eggs.

One common method of fighting these pests is to kill the parasites upon the animals' bodies. Thus cattle and sheep are dipped to kill the ticks. Sodium fluoride is dusted among the feathers of a chicken to kill lice, or a small quantity of mercury ointment is rubbed into the chicken's skin. Another common method is to keep poultry houses, stables, and other living quarters as clean and sanitary as possible. Whitewashing fills cracks in which insect parasites may otherwise hide. Disinfecting[1] chicken roosts with a spray of kerosene or crude oil is effective in killing lice and mites. Removing the manure daily from barns and poultry houses eliminates breeding places for various insect pests.

Self-test. 1. Select from the following the animal which does not belong with the rest: (1) botfly; (2) Japanese beetle; (3) flea; (4) louse; (5) ox warble; (6) tick; (7) mite.

2. State four or more kinds of damage done by insect pests which attack domestic animals.

HOW CAN MAN CONTROL CERTAIN FUNGOUS DISEASES OF PLANTS?

Agricultural production and the fungi. Insects are not the only organisms which take toll of our cultivated plants. There are many kinds of parasitic fungi which cause damage amounting to many millions of dollars annually.

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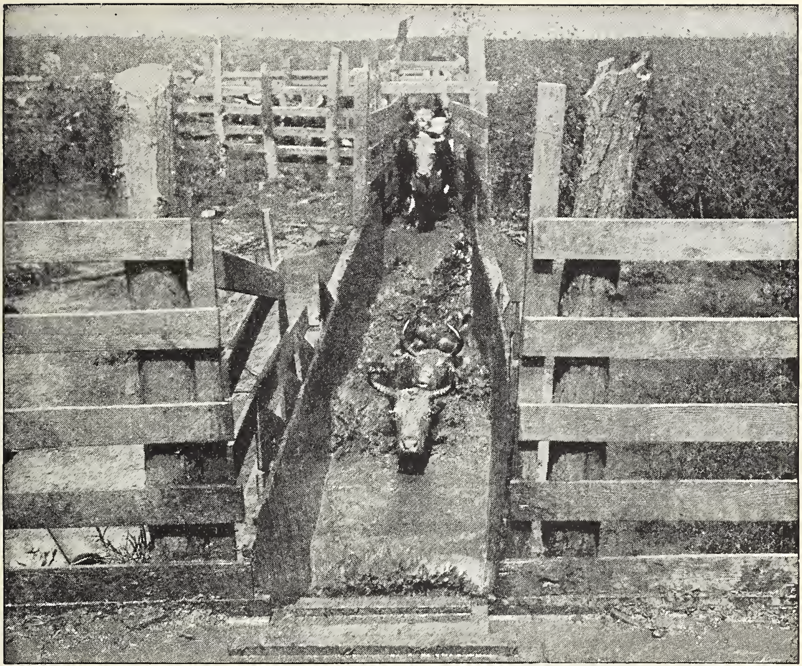
[1] *Disinfect* (dĭs ĭn fĕkt′): to kill the germs in or upon an object. *Disinfection* (dĭs ĭn fĕk′shŭn): act of disinfecting. *Disinfectant* (dĭs ĭn fĕk′tănt): a substance which kills germs.



United States Bureau of Animal Industry

Dipping cattle for ticks. Such parasites as the mange mite and the screw-worm also attack the skin. **Special Report:** Consult an advanced textbook of entomology or zoology for facts about these parasites

Among these are the bacteria, rusts, smuts, mildews, and blights. Few of our crop plants are free from the attacks of some of these.

Wheat rust. Perhaps the most serious of plant diseases are the rusts, which affect wheat, oats, barley, and rye. The common wheat rust appears on the stem, leaves, and even the grain itself, forming red patches. The thread-like body of the parasite extends into the plant tissues, absorbing the food material and destroying the protoplasm. As a result of the destruction of the food-making tissue the grains are light and wrinkled. Also, the wheat plant becomes so weakened that it may easily be blown over by the wind.

In its development this parasite, like others we have studied, usually requires two hosts. These hosts are the wheat plant for one stage and the common barberry for the other. The red spores are produced throughout the summer and may infect[1] one wheat plant after another. Later in the summer

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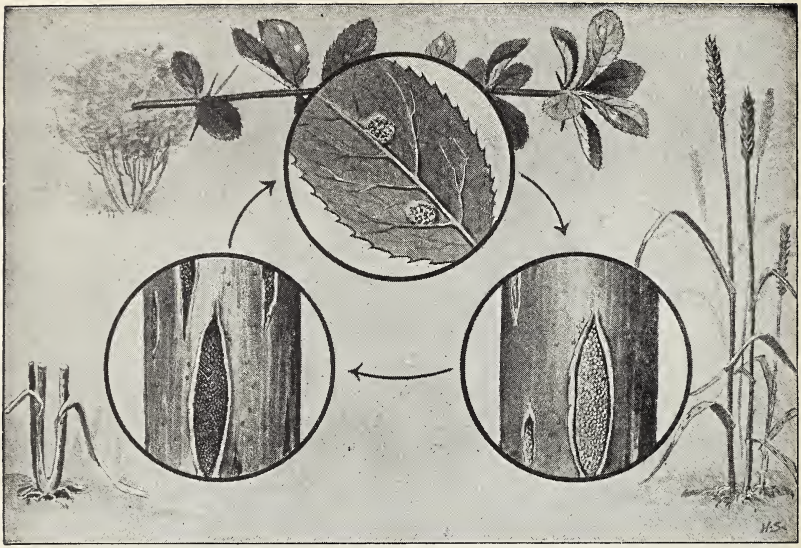
[1] *Infect* (ĭn fĕkt′): to inoculate with organisms which cause disease.



Life cycle of wheat rust. Can you explain this diagram? (See text)

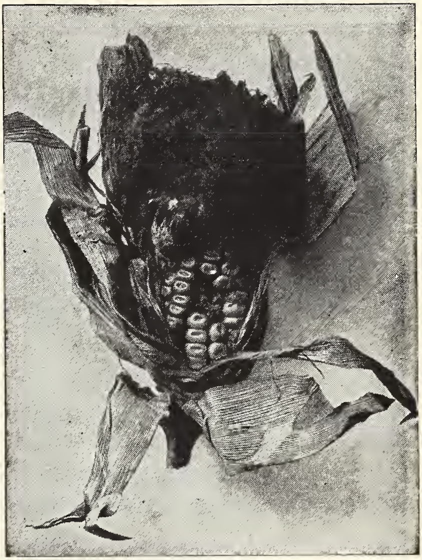
the fungus produces black spores which live through the winter on the stubble, on grasses or weeds in or near the field, or in the soil. In the spring these black spores produce a third type of spore, which is carried to the barberry by the air. Here it grows and produces a cup-like pit on the under-side of the leaf. Within this depression are formed many spores which may again infect the wheat.

In the case of any parasitic organism which requires two hosts for its life cycle, the destruction of either host results in the destruction of the parasite. If, then, the common barberry is removed from the vicinity of wheat fields, there is little probability that rust will attack the wheat. In 1903 Denmark destroyed all the common barberry bushes in the country, with the result that it has not since been troubled with rust.

It has been discovered that in warmer regions, where the host plants are not killed during the winter, the red-spore stage of the rust may live on certain grasses and weeds and infect the young wheat when it appears. Where winter wheat as well as spring wheat is planted, the rust may be present on the wheat all the year round. The only methods of reducing the danger from rust in such regions are (1) removing from the field all weeds and grasses which might harbor rust and (2) planting varieties of wheat that have been found to resist the disease.

Other rusts. There are other rusts which do great damage to cultivated plants and which have similar life cycles on two hosts. A rust which attacks the fruit of the apple tree spends part of its life on the cedar. Here in the fall it produces "cedar apples." These are round dark-brown growths on the cedar branches. In the late spring, following a warm rain, the cedar apples produce millions of spores which give them a yellow and jelly-like appearance. These spores are blown everywhere and infect the new apple leaves. No way of controlling this disease has yet been discovered except to remove all cedar trees from the vicinity of apple orchards.

White-pine blister rust, a fungous disease recently introduced to this country, is proving extremely destructive. The alternate host in the life of this parasite is a gooseberry bush or a currant bush.



Corn smut. **Special Report:** Compare the life cycle of corn smut with that of wheat rust. (Consult an encyclopedia; also, see "How to Study," p. ix)

Other fungous diseases. Smuts attack corn, oats, wheat, and barley, and produce masses of spores which destroy the infested grain. The spores are carried over from one year to another on any remaining good grain or in the ground.

Mildews attack the leaves of many plants, as the lilac, cherry, and peach. They may cover the entire surface of the leaf, making it look as if it had been powdered. Poison sprays are sometimes effective in controlling mildews.

Potato wart is a serious disease which was introduced into the United States in 1911. Since then it has spread over most of the eastern part of the country. The fungus produces spongy growths on the surface of the potato tuber. The spores are developed in these growths. Control measures consist of destroying diseased potatoes and of planting other crops in the infected soil. It is said that the spores of potato wart can live in the soil for as long as eight years.

Potato blight is a fungous disease of the leaves and stems of the plant. It may be prevented if the potato plants are sprayed with Bordeaux mixture at regular intervals during their growth.

Self-test. **1.** Select from the following names the one which does not belong with the rest: (1) mildews; (2) bacteria; (3) smuts; (4) blights; (5) plant lice; (6) barberry; (7) potato wart.

2. In order to complete its life cycle the wheat rust requires *alternate* hosts.

3. Select from the following the name which does not belong with the rest: (1) gooseberry; (2) barberry; (3) red cedar; (4) currant; (5) white-pine blister rust; (6) wheat; (7) oats; (8) rye; (9) barley.

4. The fungous parasites of crop plants are reproduced by *seeds.*

5. The fungous diseases of crop plants are *saprophytes.*

6. The most serious of the fungous diseases are __?__.

Self-test on Important Biological Terms

erosion
irrigation
nitrogen cycle
nitrogen-fixing bacteria
soil bacteria

Self-test on Biological Principles. **1.** What evidence can you cite to illustrate this biological principle: "All the higher forms of life are dependent either directly or indirectly on soil bacteria for their nitrogen intake"?

2. Can you state a biological principle which is implied in "whether man or the insects will finally conquer in their constant warfare"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. **1.** How many examples of parasites requiring alternate hosts have been discussed in this book up to this point? After you have made your list, check it against the references under "Alternate hosts" in the Index.

2. Why is it that soil is rarely found consisting of only one kind of particles?

3. Can you name examples, not given in this text, of the dependence of plants upon particular kinds of soil?

4. Why is it that soil bacteria are most numerous in soils that contain the most humus?

5. Why are soil bacteria more numerous near the surface than deeper in the soil?

6. Of the animals named in this chapter as enemies of insect pests, which are parasites? which eat the pests as prey?

7. Why is it a good practice to permit leaves and other plant parts to remain on the ground until they decay? When might such a practice be undesirable?

8. Are plants which grow along roadsides useful or harmful? Why?

9. Are the bacteria of decay parasites or saprophytes? Explain.

10. Do the nitrogen-fixing bacteria which grow on clover roots furnish an example of parasitism, saprophytism, or symbiosis? Explain.

Exercise on Scientific Method. 1. *Making Inferences from Data.* Useful scientific knowledge has sometimes been acquired by chance. For example, the grape-growers near Venice, Italy, were bothered by thieves who stole the grapes from the vines near the roadsides. One farmer dusted his grape vines with powder made from copper sulfate (blue vitriol), thinking the thieves would avoid this poisonous substance. Later the farmer observed that the vines which he had dusted produced fruit that was not injured by certain diseases which infested the fruit from other vines. On the basis of this chance discovery a method was devised for using a spray of Bordeaux mixture (containing copper sulfate) which protected the grape plants but which did not make the grapes poisonous as food.

Can you insert a sentence just before the last one in the preceding paragraph which will indicate what inference the farmer drew from his observations?

2. *Using Controls.* What served as controls in the observations which led the farmer to make his important discovery concerning the use of copper sulfate in grape culture?

Project 20. To kill any insects found on plants in the home or greenhouse. Watch the insects to determine how they feed. Which of the methods given in this chapter will you use to kill them? Consult reference books or visit a florist to learn what poisons will kill the insects without injuring the plant. Report to the class on your methods and their success in getting rid of the pests.

Special Reports. 1. What household pests are most common? How are they injurious? How can they be exterminated? Consult bulletins from the United States Bureau of Entomology and Plant Quarantine.

2. What special conservation measures were employed during the Second World War? What conservation measures do you think will continue to be necessary in the postwar period?

3. Make a list of the important pests of your state; of your vicinity. From the United States Department of Agriculture secure bulletins explaining how these pests may be combated. Report the success of these measures.

4. Read in Paul de Kruif's *Microbe Hunters* the story of the discovery that the tick carries Texas fever.

5. Read in Paul de Kruif's *Hunger Fighters* the story of the development of rust-resistant wheat. Write to the Bureau of Plant Industry, United States Department of Agriculture, for up-to-date information concerning the amount of damage done by wheat rust; white-pine blister rust; potato scab; potato wart; cabbage yellows.

6. Write to the United States Department of Agriculture for the most recent information concerning the areas which have been made unfit for agriculture because of dust storms, the progress which is being made toward reclaiming this land, and other phases of the problem of wind erosion.

CHAPTER XIV

The Conservation of Natural Resources and Wild Life

Questions This Chapter Answers. 1. What is meant by conservation of wild life? · 2. Why should forests be conserved? · 3. What are the enemies of the forests and how are they being combated? · 4. By what means are forests being conserved? · 5. How should wild flowers be protected? · 6. Why should birds be protected? · 7. What is being done toward bird protection? · 8. Why should man protect any wild animals? · 9. What mammals are man's worst enemies? · 10. What is being done toward conservation of water animals? · 11. What work in conservation is carried on by the government?

WHAT ARE IMPORTANT REASONS FOR FOREST CONSERVATION?

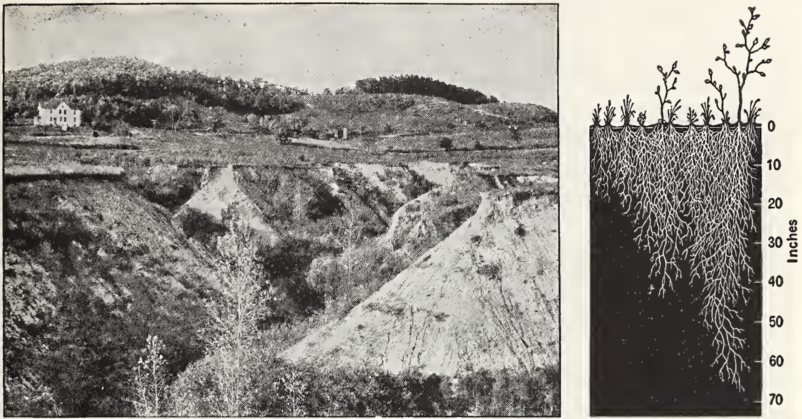
The need for forest conservation. When the early settlers came to America, fully half the land was covered by forests. Today, through cutting by men and damage by fire, fungi, and insects, scarcely half the original forest area is producing trees. Timber consumption today is said to be four times as great as timber production. At the present rate of use, therefore, the forests will certainly disappear unless there is sufficient provision for replacement.

Forest conservation, properly defined, does not mean the preservation of native forests without use. It means the using of the trees in such a manner that the value of the land as a producing property is maintained.

Value of forests. Wood still remains the best material for many uses. It is extensively used in house construction, interior finish, and furniture. Among the valuable by-products made from wood are wood alcohol, charcoal, and certain kinds of gums and dyes. Wood pulp is the cheapest and most satisfactory material for newsprint. The forests of the southern United States furnish vast quantities of tar, resin, and turpentine. Yet even now some of these articles are imported because we do not produce enough for our needs. Christmas trees are a valuable crop which provides an early and continuous return on the money invested. Their use should be encouraged. The New England states produce maple sugar in large quantities.

As a result of scientific investigations, especially those in the field of chemistry, it is reasonable to expect a great expansion in the use of wood. Recent developments in the rayon and cellophane industries illustrate such expansion.

*Forests are of value not alone because of the products they furnish. Perhaps of equal importance is their work in regulating the rate at which water runs off into the rivers and thus in preventing the erosion of soil. The surface soil in a forest is largely humus, composed of decaying leaves and other vegetation. This material acts like a sponge in absorbing rainfall and the water from melting snow. Thus it prevents water from running off too rapidly.



United States Forest Service

Erosion on a Wisconsin farm. The diagram at the right shows how plants help to prevent such erosion. How would walls help to prevent erosion?

If, however, the forests are removed, especially those around stream headwaters, the humus soil is rapidly eroded away. The hills soon become bare. Consequently the water flows swiftly down their sides, carrying with it the remaining soil and rocks. The rapidly flowing water frequently causes still further harm: (1) it adds to the volume of the flood; (2) it fills up stream beds; (3) it cuts new and deeper furrows in the land; and (4) it covers fertile valleys with stones and other material. Forests do not prevent floods entirely, but they greatly reduce the probability that damaging floods will occur.

*Forests have another important relation to rainfall. The roots take up great quantities of water during the seasons when the leaves are manufacturing food. Much of this water is passed off as vapor through the leaves in transpiration, as has been explained in Chapter VI. Later when this water vapor is cooled sufficiently, it condenses and falls as rain.

Forests have long been recognized as the natural home of wild life, and in earliest times forests were reserved and protected because of the hunting they afforded rather than for their other values. In many parts of the United States, deer and other game animals are plentiful once more in regions from which they had disappeared. Their return has been effected by providing natural homes for them through reforestation,[1] by protecting these forests from fire, and by enforcing other means of wild-life conservation, such as providing for the animals food and protection from hunters.

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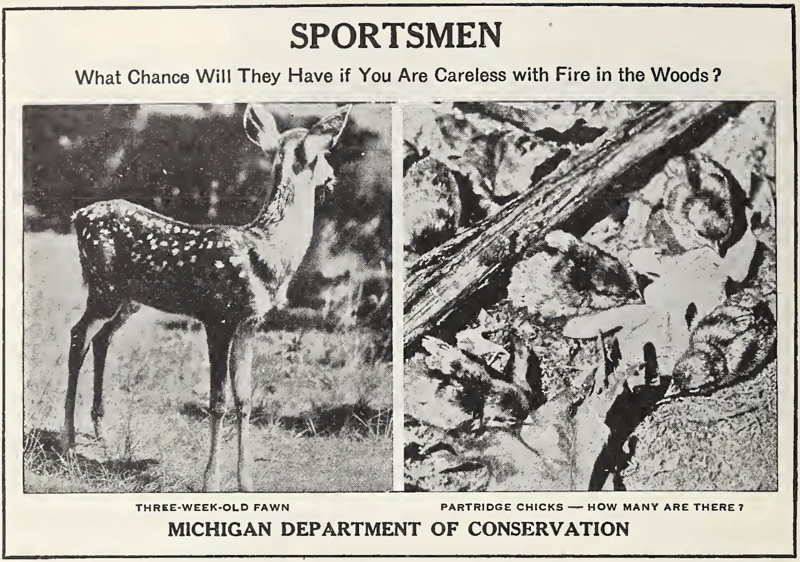
[1] *Reforest* (rē fŏr′ĕst): to renew and increase forest areas through planting trees. *Reforestation* (rē fŏr ĕs tā′shŭn): the process of reforesting.



SPORTSMEN

What Chance Will They Have if You Are Careless with Fire in the Woods?

THREE-WEEK-OLD FAWN

PARTRIDGE CHICKS — HOW MANY ARE THERE?

MICHIGAN DEPARTMENT OF CONSERVATION

A conservation poster. What protective measures, other than fire prevention, are necessary to preserve such animals as these? What can you do in your own community to protect them? What biological principle is illustrated in the second picture?

Self-test. 1. The proper kind of forest conservation provides for *no* cutting of trees.

2. State three important factors in reducing forest areas.

3. At present, forests are *increasing* more rapidly than they are *diminishing*.

4. State five values of forests.

5. The use of Christmas trees should be *forbidden*.

WHAT ARE THE MOST SERIOUS ENEMIES OF FORESTS?

Forest enemies. *Man.* Man is directly responsible for much of the decrease in forest resources. In pioneer days trees were so numerous that there was little need for care in cutting them or in using wood. Land had to be cleared to provide farms and to build settlements. But too much of the cutting was done without thought for the future. Often lumbering methods were such that not only were the smaller trees destroyed, but also tree branches and tops were left on the ground. Repeated fires occurring in these materials killed all tree growth, so that no seed trees were left. In time other vegetation also disappeared until finally all the humus covering the ground was destroyed.

Much of such bare land is of little or no value at present. Many tracts

United States Forest Service Gendreau

In how many ways do such fires damage the forests?

which were cleared for farms were later discovered to be unsuitable for agriculture because of poor soil or for other reasons. As a result, there are in the United States today about eighty million acres of idle land best suited to grow forest crops. One of the most important present-day problems is to put that land again into forest uses.

Forest fires. Fire destroys more trees than are cut for use. In 1927 thirty-eight million acres were burned over. It is estimated that it would cost three hundred million dollars to reforest this region. Each year has added similar tragedies, often accompanied by loss of human life and always by destruction of wild animals and plants.

Destruction by forest fires does not end when the fire is out. In Southern California, in particular, it has been found that after forest fires the natural openings of the soil surface are almost closed by ashes. It is difficult, therefore, for the water to soak in. As a result, most of the rain which falls runs off rapidly, causing extensive erosion.

Most of the forest fires are caused by man's carelessness. Lightning and other occurrences which cannot be prevented probably do not account for more than 10 per cent of the forest fires in the eastern part of the United

States. The other 90 per cent could be prevented. Some fires are built by people who want to clear the land for grazing or for other purposes. The fires may get beyond control and sweep vast areas. A considerable number of fires are caused by campers who build fires in dry grass or leaves, or who do not extinguish all the live coals. The careless smoker is now by far the greatest cause of forest fires. If every smoker would take care that no glowing match or burning tobacco is thrown down, the danger from fire would be greatly reduced.

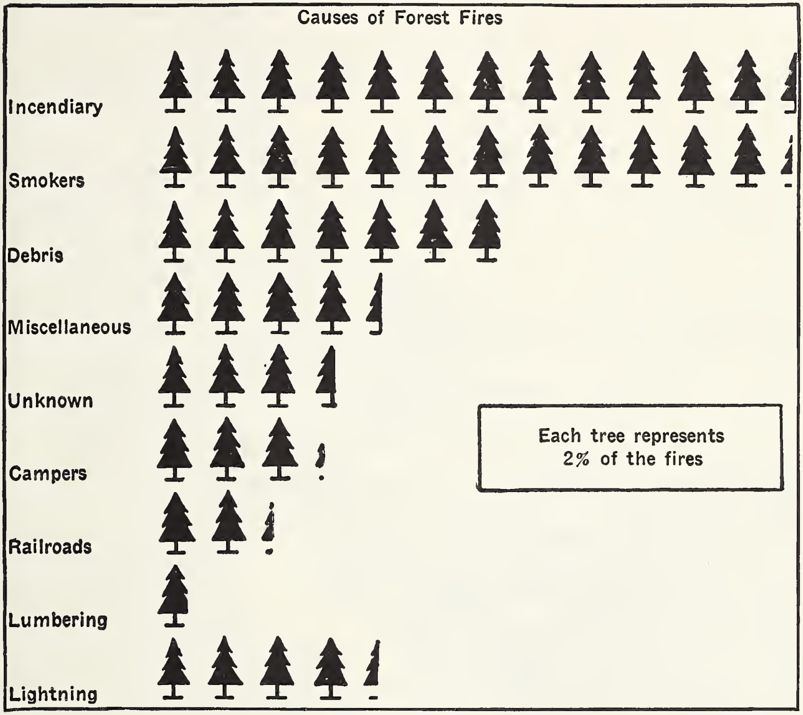
Insects. There are two hundred thousand kinds of insects which are known to attack forest trees. They do damage estimated at one hundred million dollars a year. Some feed on the leaves and thus lessen the ability of the tree to make sufficient food. Insect larvae may bore into the bark or wood, cutting off the flow of sap, ruining the tree for lumber, or perhaps weakening it to such an extent that it may be blown over by strong winds. Scale insects also do some damage.

Probably the most effective means of combating insects is through natural controls, that is, through natural enemies. Such enemies include birds and certain parasitic insects that feed on the insects that are injurious to trees. In some cases natural controls are aided by man. Thus eggs, larvae, and even the adult insects are sometimes collected and destroyed. Spraying, which is effective for orchards and shade trees as a method of insect control, is usually not practical over extensive forest areas.

Fungi. Fungous diseases of various sorts, such as the chestnut blight and the white-pine blister rust, threaten destruction of the forests in some parts of the country. Almost the only method of control of fungous diseases lies in cutting down and destroying infected trees. Quarantine laws which keep out undesirable insects and fungi introduced from other countries are also effective as controls.

Waste. Waste in the use of forest resources is as bad as any other waste. Sometimes, however, a so-called waste is in reality only a loss. It may cost more in time or energy to use a thing than to leave it unused. Cutting off the slabs in making lumber is not waste, since boards of useful dimensions could not be made from the outside portions of the logs. Leaving branches and twigs in the woods to decay is not a waste if there is no market for them. They should, however, be piled or otherwise placed so that a forest fire could not make its way through the cut-over lands by means of them.

Owners of forests who harvest their timber in such a way that lands best fitted for continuous forest crops are left completely bare are guilty of waste. High stumps and good logs left in the woods, and trees which are damaged by careless cutting, also constitute a waste.



The chief causes of forest fires.[1] How many practical suggestions can you make for reducing the number of forest fires?

Self-test. 1. The most serious enemy of the forests has been (1) fire; (2) lightning; (3) insects; (4) man; (5) fungi.

2. *All* land where forests have stood is unsuitable for agriculture.
3. Lightning is the cause of a *relatively large* proportion of forest fires.
4. Tobacco has been indirectly the cause of *much* forest destruction.
5. Certain *parasites* are effective in killing some insects which attack forest trees.

BY WHAT MEANS ARE FORESTS CONSERVED?

Forest conservation. European countries have passed through the stage of having vast natural resources and later experiencing their absence. Many European countries, therefore, can point the way to the proper use and care of forests. They discovered years ago that forests are profitable investments. They therefore treat woodland much like any other crop-producing area. Mature trees are cut and used, the smaller trees are protected from injury, and seedlings are planted to replace the trees that are removed. Thus there is a continuous supply of wood ready for all needs.

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[1] Facts from the United States Forest Service.

*The United States once had abundant resources and few inhabitants. People were encouraged to use these resources. Then gradually these natural resources passed into the control of a few people, who often exploited them in ways that were harmful to the interests of the United States as a whole. No one appreciated the speed with which the forests were disappearing. Only recently have people recognized that there can be too much land used for agriculture. Since they believed that there was an ample supply of timber and that the timbered land was best suited for farming, there was no apparent need for keeping the land in forests. Trees were cut without regard to the younger trees, and no effort was made to leave seed trees. Sheep and cattle cropped the vegetation of certain areas too closely. The relationship between forest cover and water supply and flood control was not considered. The principle of providing the greatest possible amount of good for the greatest number of people was not recognized.

In recent times progressive owners of forest land have been concerned with practicing methods of cutting, protection, planting, and fire control which will ensure a permanent supply of timber. Where there is still much native timber, as in the western and southern parts of the United States, in Canada, and to some extent elsewhere, private owners are beginning to practice forestry. In parts of the United States where all the timber has been cut, where repeated fires have reduced the value of the land, or where natural conditions of soil and growth are not favorable, it is probable that either the national or the state government will take control.

Most of the states now have forestry organizations. Many of them own extensive forest properties. It is expected that each state will in time develop a "land-use" program which will include the development of forests, wild life, and opportunities for recreation, in addition to the establishment of better control of erosion.

Care of trees near our homes. Trees which have been injured by wind, lightning, or decay should be cared for before their ruin is complete. Broken branches and diseased parts should be first cut away. Then the cuts should be covered with paint or tar to keep out insects and fungi until the part is completely healed. Large cavities should first be made free from decayed wood and should then be filled with cement. Heavy branches should be wired or bolted together to keep them from splitting and ruining the tree.

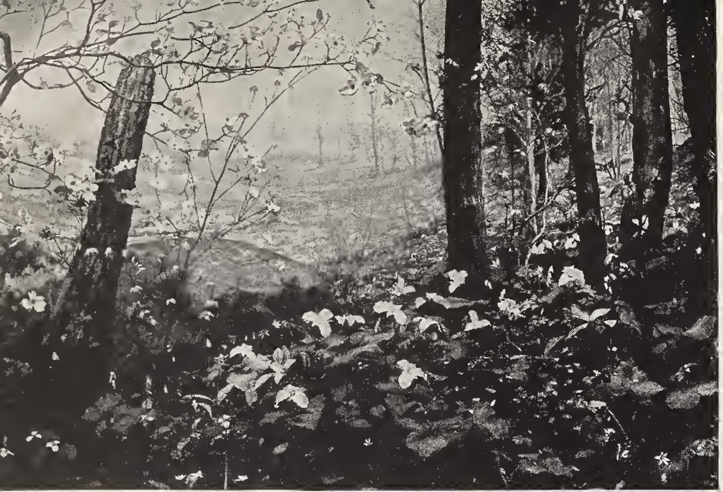
The beginning of a destructive forest fire. Special report.
How do rangers locate a forest fire?

Saginaw Forest, belonging to the University of Michigan. How does planting the trees so thickly help to produce better lumber?

Town-owned forests. There is a movement in the United States for towns to establish and maintain their own forests. Already about two thousand towns have such forests. These are located in nearly thirty states, but chiefly in New England. They cover a total of more than three million acres. The oldest town-owned forest is that of Newington, Connecticut. It was established in 1710. Most of the towns that own forests, however, have acquired them since 1890.

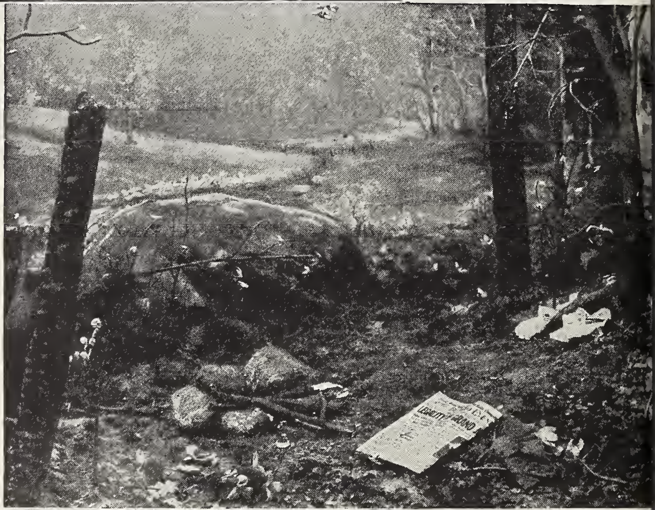
These forests have been established chiefly on abandoned farm land. Some of this land was entirely unsuited to agriculture, but is excellent for forest trees. The forests are farmed as scientifically as a vegetable, grain, or fruit farm. The forest farmer cultivates his land, plants young trees to take the places of older ones which have been removed, thins the trees so as to produce bigger and better ones, prunes them to secure desired shapes, removes brush and stumps, and harvests the crops.

The crops consist chiefly of lumber, firewood, and Christmas trees. These crops are very valuable. At the present time, in one of the New England states, there are more than five hundred great industries which get all their raw materials from forests. A few of the New England towns levy no taxes because they earn enough from their forests to pay all their expenses. Moreover,

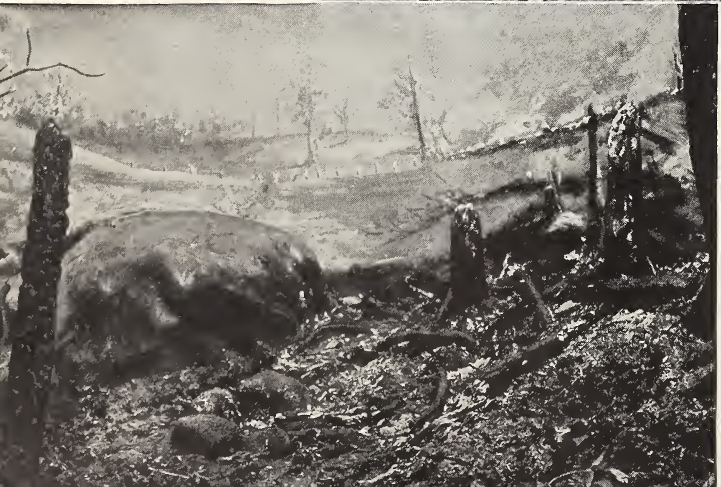


The same scene
As it was
originally

Buffalo Museum of Scienc



As it was
after
a picnic



As it was
after careless campe
had left a fire burni
How can such
destruction
of natural beauty
be prevented?

town forests have values other than the large sums of money which their crops produce. They provide beautiful parks and picnic grounds, as well as attractive drives, trails, bridle-paths, and ski-trails. Also, they provide homes for birds and other desirable animals, and promote the conservation of wild flowers.

All these town forests will continue to increase in value from year to year. They will be of greatest value to the people of several generations hence.

Wild-flower conservation.[1] The wild flowers that bloom beside the roads, in the woods, in the deserts, along mountain trails, and elsewhere add much of beauty and charm to our outings and vacations. Many people, however, are not content to enjoy flowers where they grow. They pick the wild flowers without regard to their abundance or the ability of the plant to survive when its blooms are picked. Some wild flowers—for example, orchids, especially the lady's-slipper—have always been relatively rare. Others, as wake-robin (*Trillium*), spring beauty, bloodroot, and Dutchman's-breeches, have the flower stalk and the leaves so close together that when the flower is picked the leaves are either broken or otherwise injured. This injury results in reducing or destroying the food material which would otherwise serve for the growth and the flowers of the next year. Therefore the plant may die at once from the injury, or it may later starve.

As a result of flower-picking, therefore, some plants have vanished from certain localities where they were once plentiful. It should be kept in mind, however, that, except for a few of the rarer varieties, and those used in the drug trade or sold by dealers in flowers, the numbers of flowering plants that have been destroyed by picking are exceedingly small as compared with those that have been destroyed by fires, farming, developing real estate, building roads, and developing places of recreation. Destruction of native flowers by these agencies is certain to continue and may finally result in the extermination of many kinds.

To save the wild flowers, it is necessary to establish wild-flower preserves where there will be no picking of flowers, or to provide for the protection of flowers in all wild-animal preserves. Nature trails through these wild-flower or general wild-life preserves will enable nature lovers to see wild plants and animals in their natural habitats where they are at their best.

Many people now have wild-flower gardens. In these they plant many kinds of native flowering plants. Some of these gardens are so planned that a

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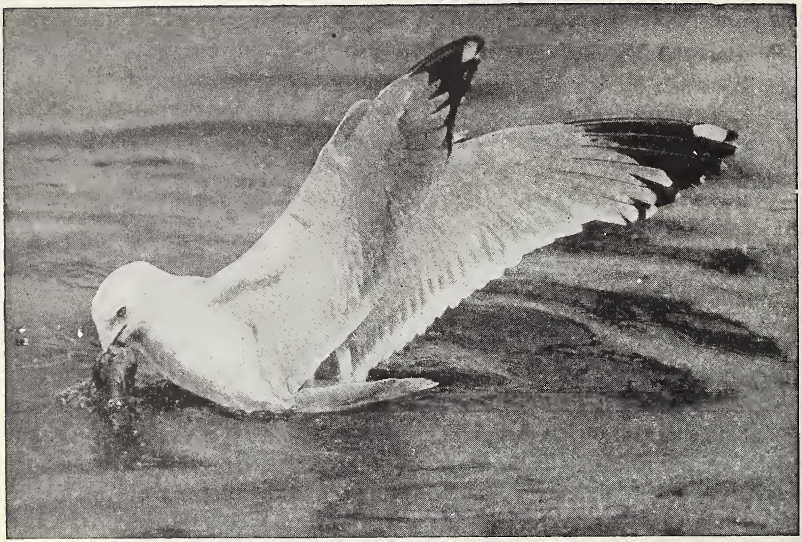
[1] The protection of native wild life is one of the chief purposes of several organizations. Most of these organizations are glad to send printed material to those who ask for it. These organizations include the Wild Flower Preservation Society, Washington, D. C.; Garden Clubs of America, New York City; Save-the-Redwoods League, San Francisco, California; International Committee for Bird Preservation, New York City; National Wild Life Federation, Washington, D. C.



Seagull. Of what importance to man is the fact that the gull is frequently a scavenger?[1]

succession of wild flowers makes the garden attractive from early spring until late autumn. Variations in color and form of flowers may thus be had throughout the whole growing season. Among the plants which usually do well in such gardens are trillium, henbane, May apple, ferns, violets, golden ragwort, phlox, jack-in-the-pulpit, Jacob's-ladder, wild sarsaparilla, and wild ginger.

The conservation of wild flowers is not merely a matter of sentiment. It has important economic values as well. Many wild flowering herbs and shrubs furnish food, nesting places, and nesting materials for birds, also food and shelter for small animals which wage a continual and effective warfare against insect pests that attack food crops.

OF WHAT IMPORTANCE TO MAN ARE BIRDS, AND HOW CAN THEY BE PROTECTED?

The value of birds. *Birds are among man's most important aids in reducing the numbers of plant and animal pests. They eat weed seeds, harmful insects, and destructive rodents, and some act as scavengers. Since most of their activities are concerned with the business of getting food, they are able to destroy enormous numbers of such plant and animal pests every year.

[1] Photograph by Frank N. Wilson. Used by permission of *Nature Magazine*.

L. W. Brownell

Phoebe feeding insects to its young. How many other birds can you name that are insect-eaters?

Birds as insect-eaters. It has been said that if it were not for the birds, within ten years the insects would become so numerous that man would find it almost impossible to live. Whether or not that statement is true, it is true that birds destroy countless numbers of injurious insects. Among the birds that feed almost entirely on insects are the wrens, warblers, swallows, woodpeckers, fly-catchers, and cuckoos. The bluebird eats cutworms, tent caterpillars, beetles, grasshoppers, and codling moths. The yellow-billed cuckoo feeds upon hairy caterpillars, such as the tent caterpillar, though most birds avoid these larvae. In the stomach of one cuckoo two hundred fifty tent caterpillars were found. The Baltimore oriole eats hairy caterpillars, and in addition it feeds upon the cotton-boll weevil, beetle larvae, and plant lice. The downy woodpecker finds most of its food on and under the bark of trees. It eats codling-moth pupae and those boring insects that are so hard for man to combat. The meadow lark feeds mostly upon beetles, caterpillars, and grasshoppers. The flicker, though belonging to the woodpecker family, feeds largely on ants.

Birds as weed-seed eaters. Much of the energy which the farmer spends in trying to raise his crops is used in combating weeds. They often grow faster than the desirable plants. As a result, they shade the seedlings from the necessary sunlight and use up the available water in the soil. In both these ways the weeds kill the crop or at least hinder its growth. It is estimated that the farmer loses a dollar an acre every year because of the damage done by weeds. He spends much of his time plowing up weeds or digging them out of pastures and fields. Moreover, he must cut those growing along

© Howard Fowler

Quails. Birds which, like the quail and the pheasant, remain through the winter are among the best weed-seed destroyers. Why is this true?

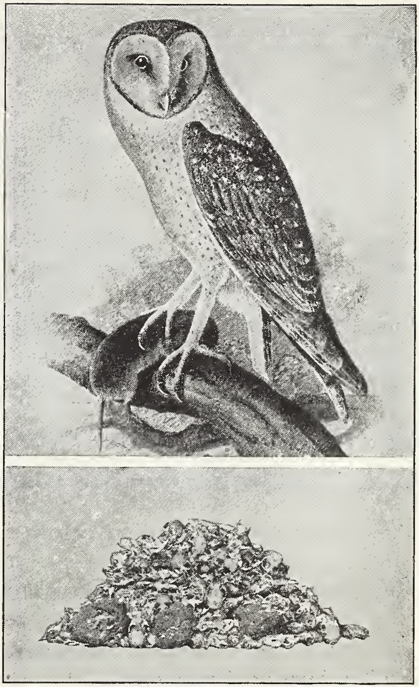
fences or roadsides before their seeds ripen, in order that the numbers of weeds in cultivated fields may be reduced the following year.

Almost three hundred species of birds are known to feed on weed seeds. Many of these belong to the sparrow family and include the native sparrows, such as the tree sparrow, song sparrow, field sparrow, and chipping sparrow, as well as the junco, the buntings, finches, and grosbeaks. Birds of other families also prominent as seed-eaters are the quail, mourning dove, red-winged blackbird, and meadow lark.

Perhaps we do not always recognize the great value of seed-eating birds as destroyers of weeds. Especially important are those birds that remain the year round, for these must of necessity feed largely on seeds in the winter. The seeds most commonly eaten are those of such weed pests as ragweed, pigeon grass, pigweed, crab grass, smartweed, and purslane.

An examination of the stomachs of various birds shows interesting facts. Several hundred seeds of pigeon grass were found in the stomach of a tree sparrow. One thousand pigweed seeds were found in the stomach of a snow bunting. Five thousand seeds of pigeon grass were counted in the stomach of a quail. Seven thousand five hundred seeds of yellow sorrel were found in the stomach of a mourning dove. One investigator estimated that the tree sparrows alone eat eight hundred seventy-five tons of weed seed per year in the state of Iowa.

Birds as rodent-destroyers. Hawks and owls are the natural enemies of the rodents which feed upon crops. Hence these birds are man's most effective aids in reducing the numbers of these pests. We do not always appreciate the economic value of such birds, because of their reputation as chicken-killers. Some kinds of hawks may kill chickens, but by far the greater number that we see circling about the fields and pastures are searching for mice, gophers, squirrels, or rabbits.



United States Bureau of Biological Survey

Barn owl and skeletons of small mammals found near its nest. **Self-test on Biological Principles:** State in complete sentences the biological principles which these pictures suggest to you

Useful and harmful birds. It is usually a mistake to label any bird as useful or harmful, because few will come wholly within either classification. The usefulness of a bird may or may not exceed its harmfulness. A bird may be of value at one time of year or in one locality and of no value in other places or at other times. For example, the bobolink is useful as an insect-destroyer in the North, but it is harmful in the rice fields of the South. The robin is sometimes condemned for eating our cultivated fruits, but over half of its food consists of insects that would destroy more fruit than the robin can eat. The turkey buzzard has been considered of such value as a scavenger that in some states there is a fine for killing it. Of late, however, there is some evidence that the bird may do great damage by carrying hog cholera and perhaps other diseases from dead animals on which it feeds to places where new victims may be infected.

The English sparrow was introduced into this country in 1851 to combat the insects that were destroying shade trees in cities. But it did not then prove of value as an insect-eater. Moreover, it threatened to crowd out native insect-eating birds, such as the wrens and the bluebirds. Many cities tried trapping, shooting, and poisoning the sparrows to get rid of them. Recently, however, in more densely populated cities where the native birds do not venture, the English sparrow is of benefit in keeping shade trees free from insects. Reports indicate that the bird is also proving of value as an enemy of the Japanese beetle and of the Colorado potato beetle.

The starling is another immigrant whose coming and rapid spread over the country have often seemed undesirable. But this bird has been found to feed on the Japanese beetle and the Colorado potato beetle; hence it may finally "pay its way."

Need for conservation of birds. Native birds have undoubtedly become less abundant than they were a century ago. Many species have been unable to adapt themselves to changing environments. As woodlands were cut and marshes drained, they retreated farther and farther from the neighborhood of man in search of breeding places and food. Some birds, like robins, martins, and swallows, seem to adjust themselves to civilization and to thrive even better than in their native state. But such birds are exceptions to the general rule.

Perhaps the hunter is most clearly responsible for the disappearance of certain birds. He has hunted birds for their skins or feathers, for food, or merely for sport. Some years ago the Chinese pheasant, one of the finest and most beautiful game birds, had practically disappeared from certain localities of the western United States where it was once very abundant. A law was passed prohibiting hunting of these birds for five years. At the end of the five years the pheasants were very plentiful.

A number of native birds have become entirely exterminated within recent times. The causes of these exterminations are not fully known. There is no doubt that hunting was at least partly responsible for the disappearance of the passenger pigeon and the heath hen. Yet it is likely that diseases or insect parasites had a large share in all such extermination. Some recent investigations into the cause of the diminishing numbers of a certain species of duck once plentiful in Middle-Western lakes revealed the presence of a small insect parasite which is believed to be chiefly responsible for the bird's rapid disappearance.

Conservation laws. While it is impossible to protect wild birds from parasites, it is possible to prevent their destruction by hunters. Laws which protect them are one means of conservation. Because of such protection the wild turkey and some of the herons which seemed on the verge of extermination are now increasing in numbers. Among the birds still threatened with extermination are the upland plover, the wood duck, and the woodcock. Although these birds are protected during certain seasons, their numbers are steadily decreasing. Further laws for their protection are needed.

George Shiras, III

Wild ducks rising from one of the ponds on the Rainey Wild Life Sanctuary, Louisiana. This refuge consists of twenty-six thousand acres, and is administered by the National Association of Audubon Societies. **Special Report:** What are the history and the purposes of the Audubon Society?

In 1886 a model law for the protection of non-game birds was drafted by the American Ornithologists Union. This law defines game and non-game birds and prohibits the killing of the latter or the collecting of their eggs. Nearly all states now have laws which are based on this one. As years have gone by, other laws which give protection have been passed. The Lacey Law prohibits the shipment of live birds out of a state in which it is illegal to kill them.

The McLean Bill (1913) forbids the killing of insect-eating birds at any time. It also provides for short open seasons when game birds may be killed, but protects them at all other seasons. In 1916 the Migratory Bird Treaty between the United States and Canada was made. In 1935 a similar treaty was made between the United States and Mexico. These laws are designed to give protection for all song birds at all times. Such laws are very important, for they protect these birds both during the nesting season and during the time when they are migrating to and from their nesting grounds.

In 1929 a Bird Refuge Law was passed by Congress. This law provides money to purchase areas for bird sanctuaries and to provide for their maintenance.

Increasing bird life. Many states have bird sanctuaries or wild-life preserves which aid in bird protection. National forests and national parks serve also for homes and nesting grounds. Then, too, many individual owners have set aside tracts of land for bird sanctuaries.

Man has taken a direct part in the propagation of certain game birds which it seems desirable to increase. The eggs of pheasants, quail, and mallards, for example, can be hatched and the young raised like poultry. When of sufficient size, the birds may be distributed to wild regions that need to be stocked again.

If we wish to encourage the presence of birds near our homes, we must provide the sort of environment they like. Trees, shrubs, or bushes will provide fruits for food and places for nests. Bird houses or boxes attract some kinds of birds. In winter, food placed in convenient feeding places will attract many birds.

Self-test. 1. Birds are important in destroying insects, __?__, and rodents.

2. The quail is especially valuable because it eats such enormous quantities of *rodents.*

3. A bird useful in one locality *will* be *useful* in another.

4. The English sparrow is of *some* economic importance.

5. *All* birds that have disappeared during the last century have been exterminated by man.

IN WHAT WAYS ARE WILD MAMMALS IMPORTANT TO MAN?

Protection of wild animals. One authority tells us that the number of wild animals in the United States today is only about 2 per cent of the number of those which once lived here. As any country is settled, the wilder animals are driven from their native haunts. Many are killed by the settlers. Others, unable to adapt themselves to changed conditions, gradually decrease in numbers.

That many kinds still exist at all is due to the passing of game laws. These laws protect certain animals at all times or at least during the seasons when they are rearing their young. Animals protected in this manner in many states include the deer, the moose, the elk, the raccoon, the muskrat, and the skunk. Other laws provide a bounty for killing certain animals, such as the mountain lion and the wildcat, which prey on deer, elk, and other animals

Beavers building a dam. How many reasons can you give for protecting the beaver?

Buffaloes, or bison. How many reasons can you suggest which justify the conservation of these animals?

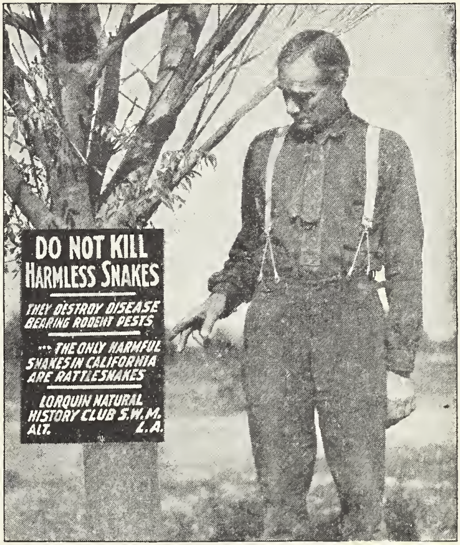
which it is desired to have increase. Still other laws have set aside suitable forest land and other lands where animals are always protected.

The degree of protection which may be extended to an animal, however, depends partly on its abundance and partly on its value or on the harm it does. Thus an animal may be protected in one state but not in another.

Values of wild animals. The reasons for protecting wild animals are not only those of sentiment. They are practical as well. Animals like the skunk are valuable insect-eaters. Many game animals, including deer, raccoon, opossum, and antelope, furnish food. Others, among them ermine, wolf, and rabbit, furnish fur of considerable value.

We are likely to think of the beaver as being valuable only for its fur. But it is also of considerable value because its activities result in conserving soil. The dams which it builds in streams prevent the water from flowing as rapidly as it otherwise would. Thus rapid erosion is checked. Also, the soil which the stream carries is deposited in the quiet water above the dam. Later, after the beaver abandons an old dam, the dam finally breaks and the pond above it is drained. The place where the pond was becomes a flat valley of rich black soil. In recent years conservation workers have stocked a number of streams with beavers, in order that the dams they build may help not only to check erosion but also to build up new soil.

In spite of all efforts to conserve wild life, many animals have all but disappeared. The bison, for example, which once roamed in vast herds over most of the United States and Canada, are now found chiefly under the protection of national parks. They had been practically exterminated by hunters, who killed them for food, for the hides, or just for sport. A few thousand are found in Yellowstone National Park, and there are smaller herds in various other national parks.


DO NOT KILL
HARMLESS SNAKES
THEY DESTROY DISEASE BEARING RODENT PESTS
THE ONLY HARMFUL SNAKES IN CALIFORNIA ARE RATTLESNAKES
LORQUIN NATURAL HISTORY CLUB S.W.M.
ALT. L.A.

John Edwin Hogg

An attempt to protect harmless snakes in California. Though snakes eat harmful rodents and insects, they are not such valuable pest-destroyers as birds. Why is this statement true?

Fur-bearing animals especially have been the victims of hunters and trappers. The beaver, for example, was almost exterminated by trappers. Now that it is protected by law, its numbers are increasing in many localities. The seals on the islands near Alaska became so nearly exterminated that all killing of them had to be prohibited for a number of years to permit them to multiply. The hunting of these animals is now closely regulated by law. Similar laws to protect the sea otter of Alaska did not prevent that valuable fur animal from being practically if not wholly exterminated.

Some fur-bearers—for example, fox, mink, skunk, raccoon, chinchilla, and muskrat—can be raised in captivity. Such animals are killed humanely and do not suffer in traps, as the wild fur-bearers do. To be successful in fur-farming, a person must learn all he can about the habits of the animal he wishes to keep. He must know the kinds of food it will eat, the type of home it prefers, its enemies, and the diseases to which it may be subject.

Rodent enemies of man. Except in remote regions, few animals are dangerous to man because they are fierce. Some, however, are enemies of man because of their ways of living. Chief among such enemies are the rodents. The rodents are very numerous; in fact, the family (Muridae) of rodents to which the mice and rats belong includes about one fourth of all the mammals. Among the rodents there are several families, as squirrels, gophers, rabbits, mice, and rats, which destroy food and property of enormous value. The squirrels and the gophers do their chief damage to farm and garden crops, though some of the squirrels also destroy birds by eating their eggs. Rabbits eat only vegetable food, including fruit. They are especially fond of garden and farm crops, such as peas, cabbages, clover, and alfalfa, and many flowering plants. They also feed on the branches and bark of young trees and shrubs, especially in winter. Thus they do considerable injury to fruit trees, to forest trees, and to trees and shrubs about the home. Rabbits are, however, of some value to man for food and also for fur, which finds considerable use under such trade names as *lapin* and *cony*.

*The rat is said to be the most dangerous pest of all the mammals. It is responsible for the direct loss of hundreds of millions of dollars annually in addition to the indirect loss caused by diseases which it and its parasites carry. The rat makes his home with man and accompanies him to all parts of the world. Rats eat most of the kinds of food used by man. They consume great quantities of grains, fruits, vegetables, and meats. Often, moreover, they injure or destroy more food than they eat. One authority says that they kill more chickens, ducks, geese, and other domestic fowls than do foxes, skunks, weasels, minks, owls, and hawks combined. They damage by their gnawing many things other than foods, including furniture, plumbing, and even buildings.

Because of its cunning the rat is a difficult animal to poison or to trap. Moreover, contrary to general belief, the house cat is frequently of little use for killing rats. The rat is ferocious. When in numbers, rats will attack any animal and in rare cases have been known to attack babies and even to kill men. Rat-proof buildings provide an effective means of keeping rats away. In Cuba, as a means of controlling rats, no building may be constructed in the cities which is not provided with a concrete or tile floor.

Mice, though less destructive and dangerous than rats, nevertheless do great damage to garden crops and farm crops and to foods of all kinds. It is estimated that a single field mouse requires from twenty to thirty-six pounds of green plant food per year. When this food consists of farm crops, it is easy to understand that the loss to a farmer from mice may be many tons per year.

Galloway

Securing eggs for fertilization in a fish hatchery. The eggs in the pan have just been taken from the female fish. Are there fish hatcheries in your state or your province? If so, what kinds of fish are raised? How are they raised?

Self-test. 1. Laws passed to protect wild animals are *always* effective.

2. The most harmful of all enemies of man among the mammals is the --?--.

3. Animals such as the muskrat and beaver are killed chiefly for their *meat.*

4. Several wild animals are raised in captivity for their --?--.

5. The mammals which are most destructive to farm crops are the *ungulates.*

6. State three values of beavers.

HOW CAN MAN MAKE RIVERS, LAKES, AND OCEANS MORE PRODUCTIVE?

Conservation of fish. *In order to prevent the capture of too many fish of valuable species most states have laws which both limit the size and number of such fish which may be taken and prescribe the methods that may be used. The laws prohibit the use of such methods as exploding dynamite in the streams, since such practices kill young fish as well as those which are large enough for use. For the same reason they prohibit the use of nets with too small mesh. Also, they forbid the catching of many species of fish during their breeding seasons.

Much damage to fishing occurs through the contamination[1] of the waters by sewage, factory waste, and oil wastes from oil-burning steamers. These wastes not only injure or kill the fish directly, but by preventing the growth of the plants and small animals which serve as food prevent the growth of young fish.

The Bureau of Fisheries has been engaged for many years in collecting information concerning the foods, the enemies, the breeding habits, and other life habits of various kinds of fish, as salmon, trout, and bass. Many fish hatcheries have been established by both state and national governments. In these hatcheries the eggs are artificially fertilized, and the young are cared for until they are large enough for their chances of survival to be good. In fertilizing eggs artificially, the eggs of mature females are carefully squeezed out into a pan of water. Sperms secured from the males in the same way are placed in the pan with the eggs. The eggs and sperms are carefully stirred to ensure a large percentage of fertilization. The fertilized eggs are placed in tanks of running water until the young hatch and get well started in their development. They may then be shipped and placed in streams and lakes.

Other water life. Oyster-fishing is one of the most important industries of the Atlantic coast. Formerly these mollusks were so plentiful that it seemed that the oyster beds could never be exhausted. About 1920, however, there was a marked decrease in the oyster crop in most parts of the world. The causes were mainly the capture of greater numbers than were replaced by natural increase; pollution of the water, which killed the oysters; and the failure of the young to start, or "set," either because too many were caught by enemies or because they could not find suitable beds to which to attach themselves.

Oysters are now protected and cultivated. They are artificially propagated somewhat as fish are. The young oysters are kept in protected places until they have passed the free-swimming larval stage. Then suitable beds of rock, shells, or twigs are provided, to which they attach themselves in great numbers. When they have grown to about the size of a quarter-dollar, they are moved to other beds where they are not crowded. Here they grow more rapidly and attain unusual size.

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[1] *Contaminate* (kŏn tăm'ĭ nāt): to make dangerously unclean; to pollute. *Contamination* (kŏn tăm ĭ nā'shŭn): act of contaminating or state of being contaminated.

VACATION-TIME BIOLOGY

The stream which flowed beside our camp looked ideal for fishing. It had many riffles where the swift water foamed over the gravel bottom. Below the riffles were deep holes of the sort in which big trout like to hide. We could hardly wait to try our skill at capturing some big fellows.

At first we were enthusiastic fishermen. Day after day we whipped the riffles and the swift water just below them, with various flies; we dragged spinners through the deep holes; we tried bait fishing, using canned salmon eggs and the larvae of the caddis fly which we found in abundance on the rocks in shallow water. We fished at twilight and at dawn. We tried every fisherman's device we knew. But the results were disappointing. We caught only a few trout, most of them under legal size. We were successful only in catching mud cats, which annoyed us by swallowing the bait whenever it remained still for an instant on the bottom. Finally we became discouraged and stopped fishing altogether.

"The stream is fished out," said Tom. "There are plenty of little trout; and perhaps in a few years, if the game wardens and the fishermen do their duty, there may be good fishing here again."

As the summer passed, the stream grew rapidly smaller. One day Bill came running into camp. "You know where the stream forks around that little island," he shouted. "The right fork is almost dry, and it is full of little fish! Come and see!"

Bill was right. All that remained of the right fork was a few small pools. These fairly swarmed with little trout, hundreds of them, so crowded together that they could scarcely swim. Many were floating dead at the top of the water.

"What are we going to do?" said Jack. "We can't let all these fine little fish die like this. In another day or so the pools will be dried up, and these fish will be dead."

"We can rescue them in pails," said Bill. "It will be a big job, but they're worth it."

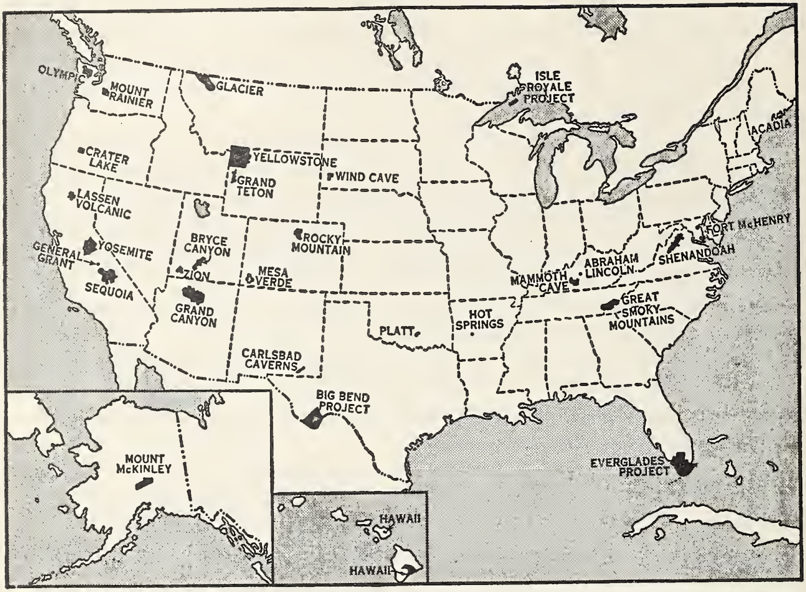
Bill and Tom got their landing nets, while Jack and I got pails. Two of us scooped the fish into the pails, and the other two carried them to the creek. Finally, after several hours of very hard work, we finished.

"Who will say we can't catch trout, now!" said Jack, laughing.

"We did not save them all," said Bill. "Some were foolish enough to hide under rocks in the pools. But we have done a good day's work in the cause of conservation."

United States Forest Service

The state conservation departments put young fish into fished-out streams. Will all these young fish grow to adult size? Justify your answer



The national parks of the United States. How do you account for the fact that so many of the parks are in the western part of the country?

Clams are protected in many places by closed seasons lasting several months of the year. Some success has been achieved in introducing, by the method described in Chapter X, desirable species of clams into waters where they are not naturally found.

Lobsters are also grown with some success in hatcheries and then planted in favorable waters. The lobster industry is further helped by laws which forbid the taking of lobsters which are too small to be of much value commercially.

Self-test. 1. *All* food fish are protected by law during their spawning season.

2. A *fish* which is valuable for food is the oyster.

3. Name several water animals which are artificially propagated for food.

WHAT WORK IN CONSERVATION IS CARRIED ON BY THE GOVERNMENT?

Preserving wild regions and wild life. There are regions possessing peculiar features which, if once destroyed, cannot be reproduced. Such are Niagara Falls, the Florida Everglades, the Okefenokee Swamp, the Yosemite Falls, the redwood and big-tree forests, the Yellowstone region, and the great

James Sawders

Maligne Lake, Jasper National Park, Canada. What kinds of wild life should you expect to inhabit this region?

mountain forests. The United States and Canada, some of the states, and a few individual citizens have undertaken to save some of these regions in which natural features and native wild life may be kept. Some of these provide illustrations of the most wonderful surface features of the earth, and furnish natural homes for many kinds of wild life. This policy of saving these regions and the animals and plants within them has developed as one of the services of the Departments of the Interior of Canada and the United States. Public-spirited citizens have been highly important factors in securing for the government some of the regions now included in national parks.

There are twenty-six national parks in the United States and nineteen in Canada. There are also many national monuments and state parks. In general, the monuments include the locations of noted historical occurrences, while the parks include unusual natural features. Each of these regions has its own peculiar surface features and to some extent its own types of wild life.

Whose are the parks? The national parks were established and are managed for the benefit of all citizens. Roads, trails, camps, hotels, and information services have been established for the use of everybody. Unusual features are maintained in as nearly their original conditions as is possible. Trained guides and instructors, printed descriptions, and explanations of important features are available.

Members of the Civilian Conservation Corps collecting seed for reforestation projects.
Special Report: The work of the CCC

Large numbers of people use the national parks. Some of these visit the parks wholly for recreation. Others seek opportunities for making scientific studies of the various features of the parks. There is usually none of these features more attractive than the wild animals and plants living in their natural habitats.

The work of the CCC. The Civilian Conservation Corps was established by the United States government in 1933 to furnish employment and training to young men who were without work. At first its work was largely concerned with reforestation. Later, however, the CCC engaged in a great variety of activities related to conservation. Although it was an independent organization, it worked with other branches of the state and Federal governments in carrying out conservation projects. At one time there were more than fifteen hundred CCC camps, in which were several hundred thousand men.

The chief types of work done by the CCC were (1) reforestation and forest protection, (2) soil conservation and flood control, (3) conservation of wild life, and (4) development of parks and other areas for recreation.

Altogether, CCC workers planted young trees on more than a million acres of land. In addition to this work of reforestation, they helped to protect forests against fires by building roads, bridges, fire towers, and telephone lines. They also helped to combat such insect enemies as the bark beetle and the gypsy moth, and such fungus enemies as the white-pine blister rust.

The CCC furnished men to help in a national program of erosion-control. The men constructed dams in small streams and gullies. They planted trees, shrubs, and grass in regions where erosion is rapid. They helped to improve highways in many sections of the country. Also, they reduced erosion of banks along the sides of roads by planting trees and grass upon them, and by placing rocks and other materials on the steeper slopes.

The organization helped to establish a number of wild-life refuges. It helped in the conservation of fish by improving the condition of many streams and lakes, and by stocking them with fish. It built more than four thousand pools for raising fish to be transferred, when old enough, to larger waters.

The CCC has helped to develop many parks and other areas used for recreation. Some of these are national and state parks, while others are smaller community projects. These are important in making the country more beautiful and more useful to greater numbers of people.

Summary of methods of wild-life conservation. *We have considered several ways to conserve wild life: (1) Laws have been passed by both state and Federal governments (*a*) to provide closed seasons, (*b*) to limit the number of animals which can be killed, and (*c*) to prohibit methods of hunting or fishing which may result in the destruction of great numbers of animals. (2) Sanctuaries, parks, and reserves have been established by Federal and State governments and by individuals. (2) Provision is being made for the increase of wild life through (*a*) artificial propagation as a means of stocking streams and woods, (*b*) providing food in winter, and (*c*) controlling enemies. (4) Such organizations as the Bureau of Biological Survey, the Forest Service, and the Bureau of Fisheries are rendering valuable service in many ways. Their investigations of the food of certain animals provide a basis for determining whether these animals are useful or harmful and for constructing a program to conserve useful kinds. Their studies of the habits of breeding and of migration help to form a basis for laws regarding hunting and trapping. The results of studies of diseases and pests which harm desired plants and animals are valuable aids in conserving wild life.

Self-test. 1. The national parks of Canada and of the United States are under the control of the *Department of Agriculture.*

2. There are *three* national parks belonging to the United States which are not within the forty-eight states.

3. Name four activities of the CCC.

4. State four ways in which our wild life is preserved.

Self-test on Important Biological Terms

conservation	reforestation

Self-test on Biological Principles. Cite evidence in this chapter of the principle "Organisms by their activities affect the numbers and kinds of other organisms living in the same habitat."

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. What is a forest community?

2. In what ways is the balance of life affected by cutting and burning over the forest, including the farm wood lot?

3. How is the forest a factor in the use of the leisure time which shortened work periods permit?

4. In what ways could changed use of now idle or low-value lands in your region promote recreational and financial welfare?

5. How does a forester produce the maximum quantity of logs which will produce lumber without knots?

6. List the direct and indirect ways in which forests affect the comfort of people.

7. Why are certain kinds of trees found together in plant societies?

8. Birds usually feed on whatever food materials are most abundant at the time. Of what particular value to man is this feeding habit?

9. During the nesting season birds probably are of more value to man than at any other time of the year. Why?

10. Can you explain how biological surveys could be made to serve as the basis for legislation in regard to wild life?

11. What more than this chapter suggests can the individual do for the protection and care of birds?

12. In what way does migration play an important part in the conservation of fish?

Exercise on Scientific Method (Making Inferences). Small mammals need to eat a far greater proportion of their weight than large mammals. How many reasons to account for this fact can you suggest?

Exercise on Social Implications. Make an outline for a ten-minute talk to be given in your biology class or your science club, on the social implications of the series of pictures on page 278.

Special Reports. 1. Discuss the history of the use of the forests and lands of your locality, your state or province, or your country.

2. What are the most destructive insect pests of your vicinity? Do birds feed on these insects? If so, what birds?

3. Salt Lake City has erected a statue of the sea gull because of the help these birds gave in combating a grasshopper plague. Report more fully on this story.

4. What bird refuges or sanctuaries are there in your state?

5. What animals are protected in your state? For which animals are there brief hunting seasons? Are there any animals that are not protected which you think should be? Are there any harmful animals which should be destroyed? (Consult your state department of conservation.)

6. What birds once abundant in your state have decreased greatly in numbers? What factors help to account for their disappearance? Look in an encyclopedia or a book on birds under *egret*, *passenger pigeon*, and *golden plover*.

7. Write to the United States Department of Agriculture for the annual pamphlet containing a summary of the laws relating to hunting seasons.

8. How is paper made? What forest products other than those named on page 270 can you list? What is celluloid? excelsior?

9. Find out as much as you can about the biological explorations of William Beebe, Martin Johnson, Carl Akeley, John Ernest Williamson, and Roy Chapman Andrews. (*Who's Who in America* will give you some information and will direct you where to look for more.)

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Hornaday, W. T. *Wild Life Conservation in Theory and Practice.* Yale University Press, New Haven.
Pack, C. L. *The School Book of Forestry.* The American Tree Association.
Weed, C. M., and Dearborn, N. *Birds in Their Relation to Man.* J. B. Lippincott Company, Philadelphia.
Wetmore, Alexander. *The Migrations of Birds.* Harvard University Press, Cambridge.

Motion-Picture Films

Forests Serve Man. United States Department of Agriculture, Office of Motion Pictures, Washington, D. C.
Our Wild Life Resources. United States Department of Agriculture, Office of Motion Pictures, Washington, D. C.
The Corn Borer and What To Do about It. United States Department of Agriculture, Office of Motion Pictures, Washington, D. C.
The Nitrogen Cycle. Eastman Kodak Company, Rochester, New York.

UNIT V · STRUCTURES AND PROCESSES

Through the microscope we may watch paramecia swimming rapidly across the field of vision. Through the window we may see a robin hopping about and stopping every few seconds with his head on one side as if to listen, or perhaps we may see a cat stalking the robin. The paramecia, the robin, and the cat are engaged in the most important activity of all living things, that of securing food.

The food requirements of different organisms vary greatly. Insect larvae, for example, must eat almost constantly in order to live. A young bird must consume sev-

CONCERNED WITH NUTRITION

eral times its own weight of food every day. A snake, on the other hand, may go months without food, and may then eat more than its own weight at a single meal.

Man and the higher chordates have many complex organs by which they secure and use food. Such a simple animal as the tape worm, in contrast, has very few organs of this sort. The simplest organisms, protozoans and algae, have no such organs.

The unit that follows deals with nutrition, that is, with the ways in which various organisms are adapted for securing food and for using it in their bodies.

CHAPTER XV

How Organisms Meet the Food Problem

Questions This Chapter Answers. 1. What different kinds of structures aid living things in securing food? · 2. How is division of labor illustrated in securing food? · 3. How did the food problem of ancient man differ from that of modern man? · 4. What are the classes of foods? · 5. In what respects is the body like an engine? · 6. What specific purposes do the different classes of foods serve? · 7. What is the relation of water to diet?

HOW DO PLANTS AND SIMPLE ANIMALS SECURE THE FOOD THEY NEED?

What is food? A major principle of biology is contained in the statement "Every organism must secure energy in the form of food." The food of the different living things, however, varies greatly. For example, certain of the simplest plants, which live on the sides of volcanoes, are able to use the element sulfur as a source of their energy. Certain fungi, as the bracket fungi, secure their food from decaying logs and trees. Some plants which are unable to secure sufficient nitrogen from the soil supplement[1] the soil nitrogen by capturing insects. Parasitic plants and animals secure their energy from living plant and animal hosts. Some animals, as the boa constrictor and the python, will eat nothing except living prey which they themselves capture. Other animals, as wolves and sharks, will eat both animals which they kill or the flesh of animals already dead. Some animals, as deer and cattle, will eat only vegetable foods. Still other animals, as rats and pigs, will eat both plants and animals. Every organism has the structures and habits of living which enable it to secure the particular foods that are necessary to its survival. It is to be expected that the ways in which all the kinds of living things get their food vary widely.

How plants secure food. As has already been explained, plants are classed as independent or dependent on the basis of whether or not they are able to make their own food. Nearly all the higher plants are independent. There are some flowering plants, however, such as the Indian pipe and the coral root, which lack chlorophyll and hence are dependent. But most of the dependent plants belong to the simplest and the lowest phylum. They are chiefly fungi.

The simplest of these plants, such as the bacteria, have no special structures for obtaining food. Hence they secure dissolved food materials by osmosis through any part of the cell walls. Some of the saprophytes, such as some of the molds and the mushrooms, have root-like structures which absorb food

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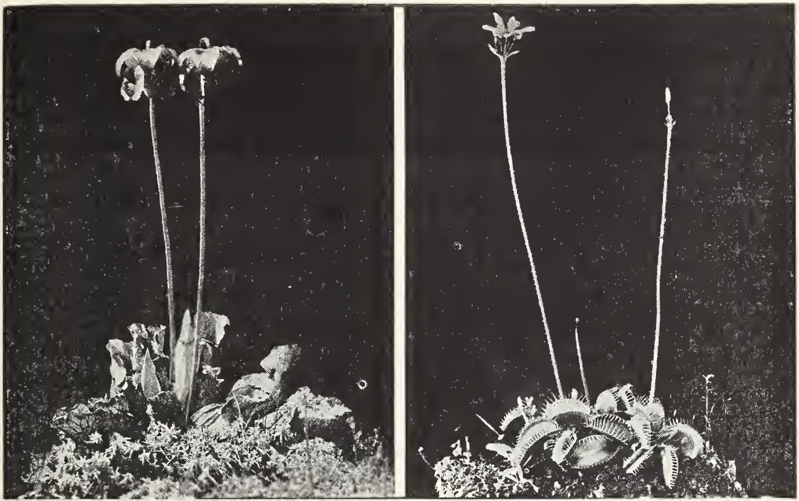
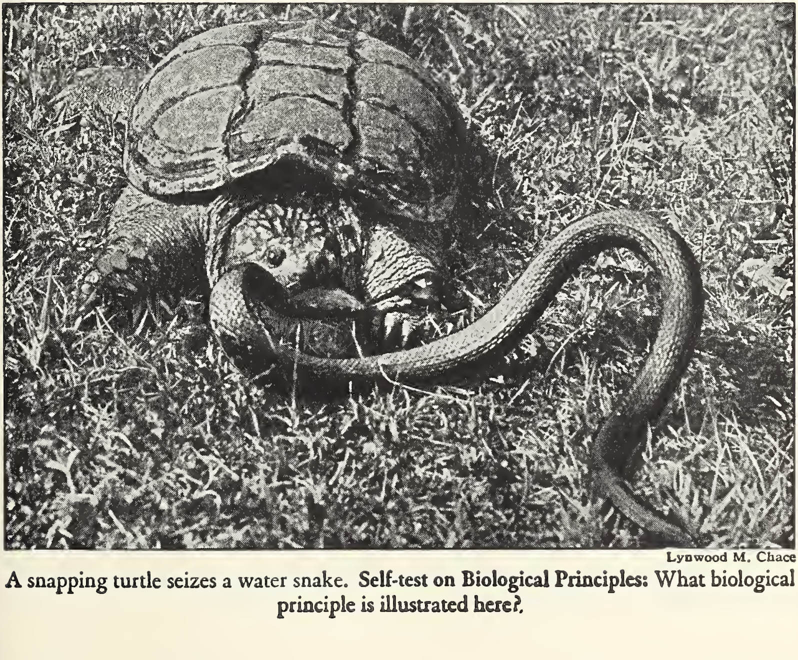
[1] *Supplement* (sŭp'lē mĕnt): to add to something or to supply what is lacking.



General Biological Supply House

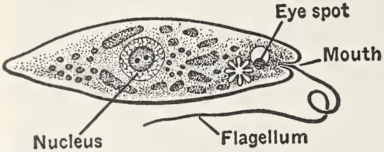
Two flesh-eating (carnivorous) plants: left, pitcher plant; right, Venus's-flytrap. **Special Report:** How do the pitcher plant, Venus's-flytrap, and the sundew capture insects? (Consult an encyclopedia or an advanced textbook of botany)



Lynwood M. Chace

A snapping turtle seizes a water snake. **Self-test on Biological Principles:** What biological principle is illustrated here?

from the organic material upon which the plant lives. The parasitic flowering plants, such as mistletoe and dodder, push their absorbing organs through the bark of the host into the phloem cells, from which they take the food materials they need.



Euglena has chlorophyll, by which it makes part of its food by photosynthesis, like green plants. It also has a "mouth," with which it takes in organic matter, like an animal. It also absorbs through its cell wall products of decay of organic matter, like a saprophytic plant. What advantages does *Euglena* derive from these varied ways of securing energy?

How animals secure food. An important difference between most plants and animals is concerned with their ways of securing food. The independent plants, those that have chlorophyll, make their own food by photosynthesis. Animals, however, can use only organic food, that is, the bodies or the products of other organisms. This is not a difference between all animals and all plants, because dependent plants, like animals, use only organic food. There are also other exceptions to this difference (as, for example, *Euglena*).

When it is recalled that the general term *animal* includes all organisms from the microscopic one-celled protozoans to the great mammals, it is easy to understand the wide variety of ways in which the different kinds of animals secure food energy. Most animals, even the simplest, have to seek for their food and capture it. To survive they must possess special structures and habits for doing this. Otherwise they and their kind would vanish from the earth. They must be able to grasp their plant food or to seize their living animal prey with teeth, claws, or other structures. Or, like the honeybee or the mosquito, they must be able to gain access to the portion of a plant or an animal where the food they need exists.

The most primitive method of securing food is by osmosis. This method serves some of the protozoans and probably most of the parasites living in the blood corpuscles, food tubes, or other parts of their hosts. Animals that feed by osmosis need not have teeth or even a mouth for securing their food, since their bodies are surrounded by nutrient liquids.

When watching an amoeba through a microscope, one may see how an animal without definite form and without specialized structures ingests[1] its food. If an amoeba comes in contact with a grain of sand or something else which it cannot eat, it crawls away from the object. If, however, it encounters something which it can eat, it immediately begins to ingest the particle. First

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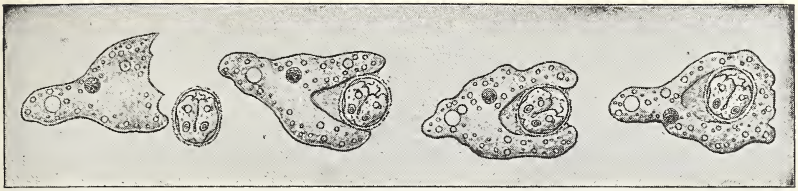
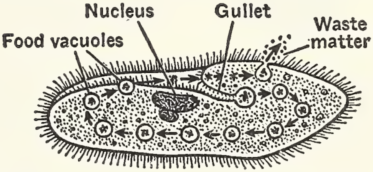
[1] *Ingest* (ĭn jĕst′): to take food into the body, to eat. *Ingestion* (ĭn jĕs′chŭn): the act of ingesting or eating.



An amoeba ingests a resting euglena (cyst). Use the pictures to explain how the amoeba secures food

the amoeba puts forth a projection on each side of the food particle. It pushes these projections farther and farther around the particle until the projections meet. The food particle, with a little of the water around it, is then completely surrounded by the protoplasm. Thus a food vacuole is formed, which looks like a bubble in water. Since the amoeba has no cell wall, any part of the body which comes in contact with food may act as a mouth in ingesting simple animals or other organic bodies.

Paramecium has a definite portion of its body which is concerned only with securing food. In this respect, therefore, *Paramecium* is a more highly specialized animal than *Amoeba.* Along one side of *Paramecium* is a funnel-shaped groove which ends in a sort of "mouth." The groove is lined with hair-like cilia. The beating of these cilia makes currents of water which carry particles of food to the mouth (gullet). The protoplasm at this point separates to admit food. Thus a food vacuole is formed. You may find many food vacuoles in the body of *Paramecium.*



Paramecium. Do the cilia of *Paramecium* have any function other than the ingestion of food? Explain

In getting its food the sponge illustrates true division of labor, since certain cells ingest food for the entire animal. Water which carries organic food particles is caused to circulate through the cavities in the animal by the movement of hair-like structures (flagella) on the living cells. These cells then capture the food particles which come in contact with them in much the same way as does an amoeba.

Hydra illustrates more complete division of labor, since it has certain structures which are concerned with capturing food. The tentacles are its food-capturing organs. These tentacles are equipped with stinging cells (nematocysts), with which it paralyzes[1] its prey. The prey consists almost entirely of small water animals, such as crustaceans or insect larvae.

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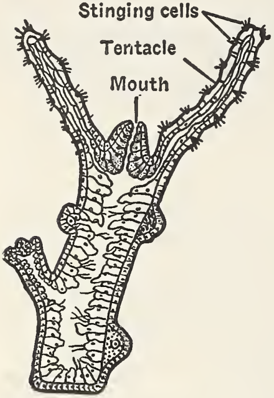
[1] *Paralyze* (păr'ă līz): to make unable to move.

If you observe a hydra placed in a small amount of water containing water fleas or other small animals, you may see how it gets its food. A water flea swimming actively about presently strikes a tentacle of the hydra. It stops at once and is unable to go on. At the moment of contact the stinging cells discharge tiny poisoned darts into the body of the water flea. The paralyzed animal is then pushed by the tentacles into the hydra's mouth.



The food-getting structures of *Hydra*. The stinging cells are scattered over most of the hydra's body. Those not on the tentacles cannot serve in capturing food. What purpose might they serve?

The earthworm may be said to eat its way through the ground. As it burrows, it swallows sand and dirt which contain decaying leaves and other organic materials. The animal digests useful parts, that is, the organic material.

The snail has a horny jaw for scraping up and holding the vegetable food which it eats. In the mouth there is a ribbon-like tongue covered with tiny teeth. The snail runs this tongue over its food material and scrapes off particles. If very numerous, snails or their relatives the slugs may become pests by eating the leaves of garden plants. But these same eating habits make them useful in an aquarium. They will keep the glass free of algae that otherwise would collect there.

Summary. *The ways in which plants and animals secure food have here been illustrated by a typical organism from each of several phyla described in Unit III. The food-getting habits of the flatworms and the roundworms, which live as parasites in the bodies of other animals, were described in Chapter X. It will be seen that in general the more complex the animal, the more complex is its method of obtaining food, and the more highly specialized are its food-getting structures. These facts are shown in the following statements:

1. No specialized structures; food can be taken in at any part of the animal. (*Amoeba*, phylum Protozoa.)

2. No food-getting organs, but a definite point of entrance for the food; also, rudimentary[1] structures for securing food and directing it into a rudimentary mouth. (*Paramecium*, phylum Protozoa.)

3. The beginnings of division of labor, with certain cells collecting the food for the entire animal. (Sponge, phylum Porifera.)

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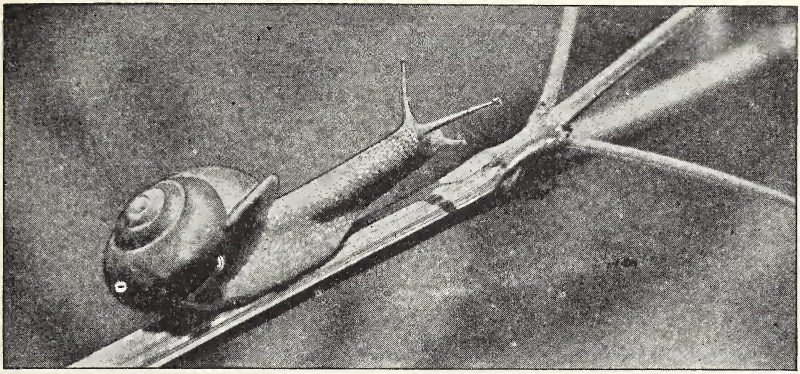
[1] *Rudimentary* (rōō dĭ mĕn′tȧ rĭ): in the earliest stages of development; not perfectly developed.



Brownell

The snail has a solid row of teeth along the edges of its tongue and also has other teeth on its tongue. Why is the animal served better by having many teeth on its tongue than it would be by having a few scattered here and there?

4. Simple organs used in securing food and putting it into a rudimentary mouth. (*Hydra*, phylum Coelenterata.)

5. A mouth actually used in securing food. (Earthworm, phylum Annelida.)

6. A mouth equipped with teeth. (Snail, phylum Mollusca.)

Self-test. 1. *Independent* plants secure their food by *photosynthesis.*

2. *Few* of the higher plants make their own food.

3. *All* parasites make *all* of their own food.

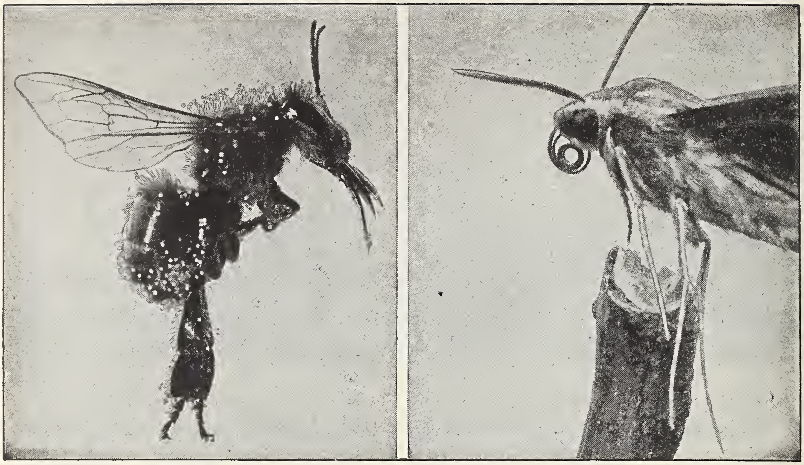
4. *All saprophytes* make *all* of their own food.

5. The lowest animal parasites secure their food by *symbiosis.*

6. Choose the best ending to the following statement: One important difference between animals and plants is that (1) all animals have legs; (2) all plants make their own food; (3) no animal is able to make its own food, though green plants can do so; (4) no plant captures living food, as many of the animals do; (5) no plants can live on organic food, while all animals can live only on organic food.

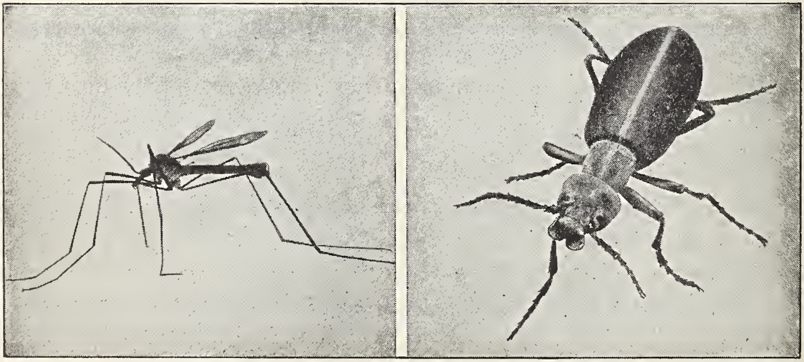
7. The lowest animal which illustrates true division of labor in food-getting is the --?--.

8. Name and illustrate the various stages of increasing complexity of methods of food-getting, as illustrated in this section.



Honeybee

Moth



Mosquito

Beetle

Cornelia Clarke

The mouth parts of insects are adapted to food habits. Which of these insects has mouth parts most like those of the grasshopper (p. 195)?

HOW ARE THE HIGHEST INVERTEBRATES AND THE CHORDATES EQUIPPED TO SECURE FOOD?

How arthropods secure food. The crayfish eats plants and small animals, including other crayfish. It also eats dead fish or other refuse. The large claws, or pincers, are used to catch the food or to hold it and tear it. The smaller pincers on the first two pairs of walking legs help to hold the food within reach of the mouth.

There are six pairs of mouth parts that together hold the food and grind it. All the parts of the mouth work sidewise—not up and down, as ours do. Three pairs of mouth parts are like small feet (maxillipeds), which hold the food and guide it to the mouth opening. Two pairs (maxillae) are flat and scoop-like, while another pair (mandibles) is hard and toothed for cutting the food.

*Insects have a variety of ways of securing food. Some live on bits of plant or animal tissue which they chew and swallow. Others suck the juices from living plants or animals. Still others use for their food the nectar produced by flowers. It is plain that no single pattern of mouth would serve all these purposes equally well. We find, therefore, that the mouth parts of an insect are modified according to the kind of food it eats.

The honeybee has a combination of types of mouth parts. There is one part fitted for sucking up the nectar of the flowers it visits, and other parts fitted for cutting and shaping wax to form the honeycomb.

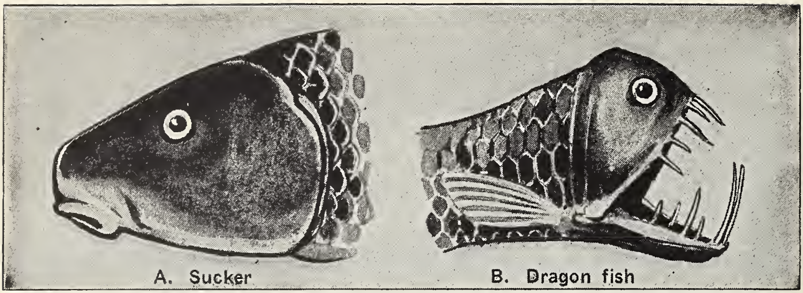
The butterfly and the moth live on the nectar found in flowers like the morning-glory and clover. Many of these flowers have very deep cups into which the butterfly's or the moth's large wings will not permit it to crawl. It has, however, a very long tube-like mouth, by means of which it reaches its food. This tube is coiled up under the head of the insect when not in use.

The mosquito is a good example of an insect that lives on the life juices of plants or animals. It has a sharp needle-like beak with which it pierces the body of its victim. The juices are then forced up through this hollow beak when reduced pressure is produced by the action of the stomach.

The beetle has a mouth fitted for chewing plant leaves and other materials. One pair of hard-toothed jaws (mandibles) serves to bite off blades of grass. These jaws move from side to side, like those of the crayfish. A second pair of jaws (maxillae) helps to hold the food and cut it. An upper lip (labrum) and a lower lip (labium) aid in holding the food. Attached to the second jaws and to the lower lip are two pairs of finger-like organs (palpi) which may be used in finding food.

How chordates secure food. The ways in which chordates secure food differ greatly from those of invertebrates. The food-getting habits of the various classes of chordates, however, are in general much alike. But they differ in certain respects, as will be noted in the following paragraphs.

The kind of food which a fish eats depends on both the age and the species of the fish. Young fish or such small fish as minnows eat small water animals of many sorts. Certain fish, including minnows of many kinds, catch insects that light on the surface of the water. Other fish, as the sea bass, the suckers, the mud cats, and the catfish of our rivers, search about in the mud or sand



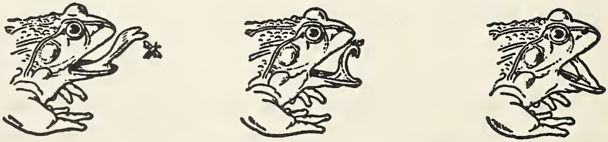
Mouths are adapted to food habits. **Exercise on Scientific Method (Making Inferences):** One of these fish preys upon fish that can swim rapidly. The other secures its food from the river bottom. Can you decide from the mouth structures which fish feeds in one of these ways?

for crustaceans, mollusks, or worms. Many fish prey upon smaller fish. These fish—for example, the bass and the crappie—have large mouths and strong teeth to seize and hold their victims. Their teeth are located along the edges of the jaws, on the roof of the mouth, and even on the tongue.

The tongue of a frog is covered with a glue-like substance to which its prey sticks. The frog uses its front feet to push larger prey into its mouth. Cone-shaped teeth, in the upper jaw and in two bones in the roof of the mouth, are used for holding the food, but are not used for chewing.

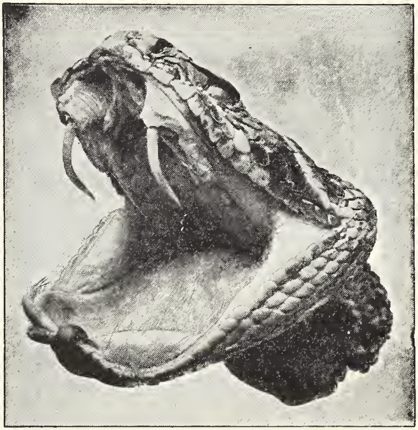
The frog eats nothing but living animals, such as insects, worms, and smaller frogs. It will starve to death when surrounded by dead flies or dead worms, but will snap at any small moving object, even a marble or a piece of cloth. It swallows its prey whole. When it swallows an object that does not prove to be food, the frog can cast out the object from its mouth.

Snakes, like frogs, eat only living prey. Our common snakes capture their food by a quick movement of the head and swallow it whole. The teeth, which are small and sharp, point toward the throat and thus aid in keeping the victim from escaping. Certain snakes, like the gopher snake and the boa constrictor, capture their prey by winding their bodies about it and crushing



How a frog captures its prey. What other animals should you expect to capture insects by a method similar to the one shown here?

it to death. In the poisonous snakes the fangs are modified teeth. These serve as an adaptation for getting food and for defense. The poison is injected, that is, forced, into the prey or the enemy to render it helpless.


New York Zoological Society

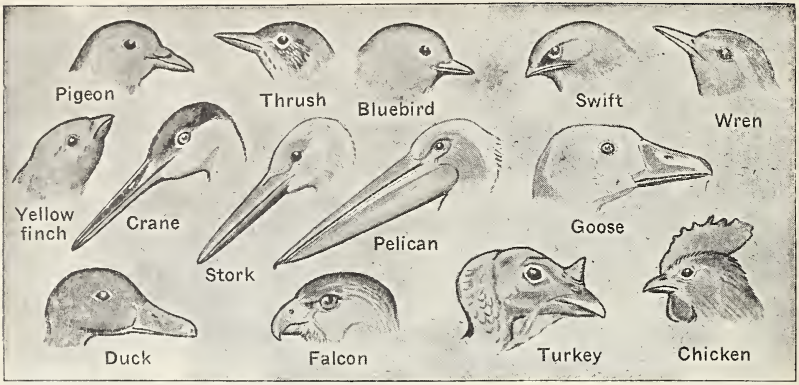
Mouth and fangs of a rattlesnake. The smaller teeth do not show in this picture. Do you think that they point toward the throat or toward the front of the mouth? Explain

For all birds, except the birds of prey, like the hawk and the eagle, the beak is the only means of securing food. We can tell much about the habits of a bird, and especially about its food, by examining its beak. The strong cone-shaped beak of the sparrows is well fitted for crushing weed seeds but is less useful for catching insects. The slender pointed beaks of the nuthatches and warblers are adapted for securing insects from under bits of bark or from twigs. Owls and hawks have hooked beaks, well adapted for tearing apart their prey. The woodpecker has a very strong and sharply pointed bill with which it drills holes in wood so that it may locate the boring insects which form its chief food.

Birds swallow their food whole. No present-day bird has teeth set in its jaws, as did its ancient reptile-like ancestors. Some kinds of beaks, however, have toothed edges which help the bird in grasping and holding food.

Most mammals make considerable use of their teeth in securing food. The kind of teeth an animal has is always closely related to the kind of food it eats. Thus, the dog, like other carnivorous animals, has long sharp teeth called canine teeth, or canines, on each side near the front of the jaw. These are fitted for catching and killing the animals it preys upon. The teeth along the sides of the jaws have each a single ridge lengthwise. When the jaws come together, these ridges act like the blades of shears, cutting the food into pieces small enough to be swallowed whole.

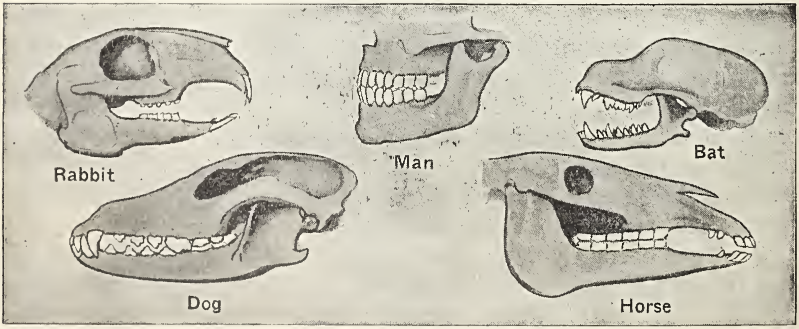
The teeth of a plant-eating (herbivorous) animal, such as the horse, are very different from those of the dog. The front teeth, or incisors, are long and broad. They are fitted for cutting off grass or other vegetation. The molars, or back teeth, are flat and heavy for grinding food that otherwise would be hard to digest.



Types of birds' beaks. **Exercise on Scientific Method (Making Inferences):** Can you decide from the appearance of the beak what kind of food each bird probably eats? Check your inferences by consulting a "bird book." (See page 299)

Insect-eating mammals, like the bat, have many small sharp teeth for crushing their food. The gnawing animals, like rats and mice, rabbits and beavers, have chisel-like incisors that grow continuously. As they are used, they wear down and keep a sharp cutting edge. Animals which, like man, eat all sorts of food (omnivorous animals) have incisors for biting off pieces of food, canines modified to help in biting and in tearing tough foods, and molars for grinding.

The teeth of many mammals, as of many other kinds of animals, are adaptations for defense as well as for food-getting.



Teeth of various mammals. Can you explain the relation of food habits to the structure of the teeth of these animals?

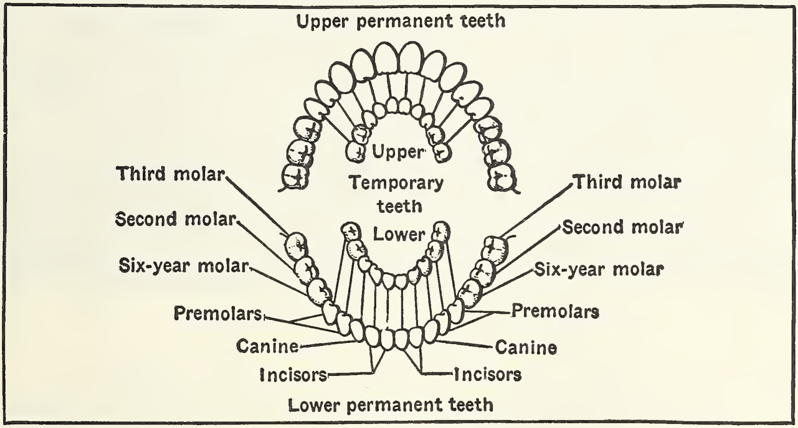
Self-test. 1. The mouth parts of *few animals* vary with the kinds of food they eat.
2. Match each phrase under *B* with one or two phrases under *A*.

A

a. Salmon and bass
b. All vertebrates
c. Black snake and gopher snake
d. All chordates
e. Insects which live on the blood of living animals
f. Leaf-eating insects
g. Honeybees and wasps
h. Tapeworms and liver flukes
i. Hawks and eagles
j. All arthropods
k. Protozoa

B

1. Animals that crush their food before swallowing it whole
2. Having only sucking mouth parts
3. Biting and chewing mouth parts
4. Claws to hold food
5. Animals which swallow their food whole immediately after capturing it
6. Animals which use their feet in capturing their prey



Temporary, or deciduous, and permanent teeth of man. The twenty "baby" teeth are called deciduous because they are later shed, or lost. In what respects are deciduous teeth like the leaves of deciduous plants?[1]

WHAT ARE SOME OF MAN'S FOOD PROBLEMS?

Ancient and modern food problems. Primitive man spent much of his time in search of food. Having no means of storing or preserving foods, he was forced to roam the forests in search of fruits, nuts, plants, and such animals as he could kill. Always he must be keenly watchful lest he himself be captured for food by some other animal. If food happened to be scarce, he was forced to go without until he could find it. If he happened to find food in plenty, he made the most of his good fortune by gorging himself with a far greater quantity than present-day man would attempt to eat at one meal.

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[1] To the Teacher. If it seems desirable to consider at this point the hygiene of the teeth, that material will be found in Chapter XXVI.

Contrast primitive man's problem of securing food with that of modern man. Ships bring us staple foods and delicacies from every part of the world. In our gardens, orchards, and farms we grow all sorts of food crops, most of which have been introduced from other parts of the world to supplement our own native plants. Modern means of transportation and refrigeration[1] make it possible for us to obtain at all seasons of the year fresh fruits and vegetables from foreign lands, as well as from all parts of our own country. Fresh foods are supplemented with canned meats, fish, fruit, and vegetables in great variety.

Classes of foods. *In spite of the fact that the various things we eat look and taste very different, they may all be placed in two groups: (1) those which yield energy and (2) those which do not yield energy.

*The energy foods are of three classes: carbohydrates, proteins, and fats. All are essential to life. Of the foods which do not yield energy, some are necessary to life, and some are not. Those necessary to life include (1) vitamins, (2) various mineral salts, and (3) water. The non-essential (accessory) foods include (1) the food flavors, (2) the condiments, that is, mustard, pepper, and similar substances, and (3) the stimulants,[2] such as coffee, tea, and cocoa.

Why we need food. *The food used by all living things serves three chief purposes: (1) it furnishes all the materials for building protoplasm; (2) it supplies energy for all the activities of protoplasm; (3) it supplies substances necessary for the health and proper growth of the organism. All the processes which have to do with the use of food in the cell are included in the term *metabolism*. Thus metabolism includes (1) the release of energy, (2) the building of protoplasm, and (3) the elimination of wastes from the cell.

If a person were to try to remain entirely inactive, he would nevertheless use up considerable energy. His life processes, such as breathing, digestion, and blood circulation, would of course continue. These processes would consume energy, not only for necessary movement, but also for growth and for replacement of worn-out cells. In the process of eating he would use additional energy. Still more energy would be necessary if he did any work at all. If he were an office worker, he would use less than twice as much energy daily as he would in lying as nearly motionless as possible. If he did

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[1] *Refrigeration* (rē frĭj ẽr ā'shŭn): the act or process of preserving foods and other substances by keeping them at a low temperature.

[2] *Stimulant* (stĭm'ū lănt): that which stimulates, that is, excites and makes more than normally active. *Stimulation* (stĭm ū lā'shŭn): act of stimulating or state of being stimulated.

Gendreau

Why does outdoor exercise increase one's appetite?

light muscular work, he would use only about three times as much energy as if he lay motionless all day. If he were engaged in hard muscular labor, he would use nearly ten times as much. Food is needed to supply this energy. If he ate nothing, the reserve energy stored as sugar and fat in the body would first be consumed. Then the protoplasm of the body tissues themselves would be used up as fuel.

The energy which our bodies require can be accurately measured in Calories. A *Calorie* is the quantity of heat energy required to raise the temperature of one kilogram of water (1000 grams) through one degree centigrade.[1] Thus the average city dweller needs about 2500 Calories of energy per day in performing all his life activities. The man at hard labor requires from 3500 to 5000 Calories. This last amount of energy would be equivalent to that required in lifting a ton nearly one and a half miles.

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[1] This is the great Calorie. The small calorie, as defined in physics, is the quantity of heat energy required to raise one gram of water through one degree centigrade.

The body like an engine. The human body can be roughly compared to the gasoline engine. The gasoline is the potential, that is, the stored, energy. When the engine is started, this potential, or chemical, energy is converted chiefly into two forms: (1) the mechanical energy of the moving parts and (2) heat energy, as a result of the chemical changes of combustion. Further heat results from the friction in the moving parts. In the body the food is the potential energy. It is fuel, just as gasoline and coal are fuel. It is burned, or oxidized, in all the living cells of the body, as gasoline is burned in the engine. The food energy is transformed chiefly into the same forms of energy into which the gasoline is transformed in an automobile engine: (1) the mechanical energy of movement and (2) heat energy. The heat energy here, as in the gasoline engine, results from the combustion of fuel. Also, further heat results from the friction of moving parts.

Like the moving parts of any machine, the muscles of the body are not very efficient; that is, much more energy is put into them than is transformed into useful work. Even the heart, which is perhaps the most efficient of all the organs of the body, transforms in its movements only about 20 per cent of the energy which is supplied to it. Most of the energy which is not transformed by muscles into useful movements is transformed into heat. In the body, as in the engine, and whenever any sort of fuel is burned, the chief products of the combustion are carbon dioxide and water.

Self-test. 1. Name the kinds of food that do not yield energy.

2. The three types of energy foods are --?--, --?--, and --?--.

3. The process which includes the use of food by the cells and the release of energy is called *photosynthesis.*

4. We use *no* energy when we remain quiet.

5. Heat energy is measured in *degrees.*

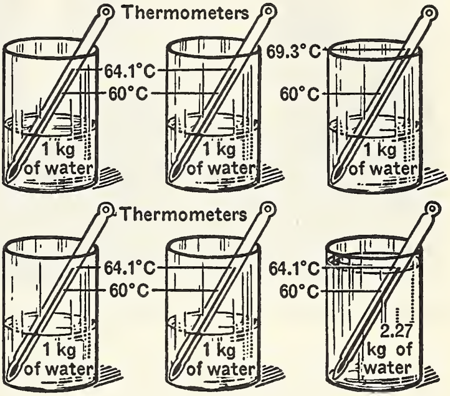
6. Food energy is transformed in the body into --?-- energy and --?-- energy.

7. Whenever fuel, such as coal in an engine or food in a living cell, is burned, or oxidized, two waste products are always formed. These are --?-- and --?--.

WHAT ARE SOME IMPORTANT FACTS ABOUT THE ENERGY FOODS?

The energy foods. As has been already stated, every living thing is using some energy every instant of its existence, even when it is as inactive as possible. Of the food materials mentioned earlier in this chapter, only three can serve as fuel to release energy. These are carbohydrates, proteins, and fats. Carbohydrates and proteins furnish each 4.1 Calories of heat energy per gram, and fats 9.3 Calories per gram. These facts are shown in the diagram.

Most of the things we eat contain more than one of the foods which supply energy. It is difficult to find substances which contain only one of the three nutrients. Usually foods contain some of each one of the three,—carbohydrates, fats, and proteins,—though the proportions differ greatly. It is easy to test for these nutrient substances.



These two rows of vessels represent the fact that a given weight of either carbohydrates or proteins furnishes less than half as much heat energy as an equal weight of fat. Explain how the figure shows this

Experiment 43. 1. How may one determine whether a given food contains sugar? To find a test for a given substance it is necessary to have both a test substance and a control (see the Glossary). In this experiment take a simple sugar, such as glucose, for the test substance and another substance which contains no sugar at all, such as white of egg, for the control. Put into one test tube a little of the glucose and into another a little of the egg white. Add to each a little water and a few drops of a mixture of Fehling solutions A and B. Heat the mixtures. What do you observe in each test tube? Any substance containing sugar will act like the glucose in this test when treated in this way. Make the test, therefore, of a number of foods, such as candy, honey, beans, bread, meat, and so on.

2. How may one determine whether a given food contains starch? For the test substance use corn-starch, and for the control use sugar. Put into one test tube a small amount of starch, and into another a small amount of sugar. Add to each a little water and heat the mixtures gently. Then add a few drops of iodine solution to each. What color changes do you observe? Any substance containing starch will act as the corn-starch does in this test. Now test several foods for the presence of starch.

3. How may one determine whether a given food contains protein? For the test substance in this case choose white of egg, which contains a considerable amount of protein, and for the control use sugar, which contains none. Boil a sample of each in a little water; then add a small amount of nitric acid and heat the mixture gently. After a few moments add a little ammonium hydroxide, *a drop or so at a time.* What do you observe in each test tube? The effect you observe with the white of egg

What carbohydrate foods are shown in these pictures? Explain how each comes directly or indirectly from plants

indicates the presence of protein. Make the protein test now of a number of food substances, such as milk, meat, honey, beans, bread, and so on.

4. How may one determine whether a given substance contains fat? Use for the test substance something which you know contains fat, such as lard or butter. Use for the control something which you know does not contain fat, such as a cube of sugar. Rub each sample upon a sheet of paper; then hold the paper toward the light. What happens with each sample? Test various food substances for fat.

Record the results of these tests as in the following table. (*Do not write in the book.*)

Food Tests

Name of Food	Sugar	Starch	Protein	Fat
Corn-starch	?	+	?	?
White of egg	—	?	+	?
Sugar	+	—	—	—
Bread	?	?	?	?
--?--	?	?	?	?
--?--	?	?	?	?

Add the names of the other foods which you tested, placing in each column a + if the food contained the substance indicated and a – if it did not. Compare your results with those obtained by other members of the class. In all cases where various members disagree, the tests should be carefully repeated until you are all sure which are the correct answers.

Explain the purpose of the controls in these experiments. Evaluate the procedures by answering these questions: What was the purpose of repeating the experiments when the different members of the class disagreed in their results? If all the mem-

What foods containing fats are shown in these pictures? What others can you name?

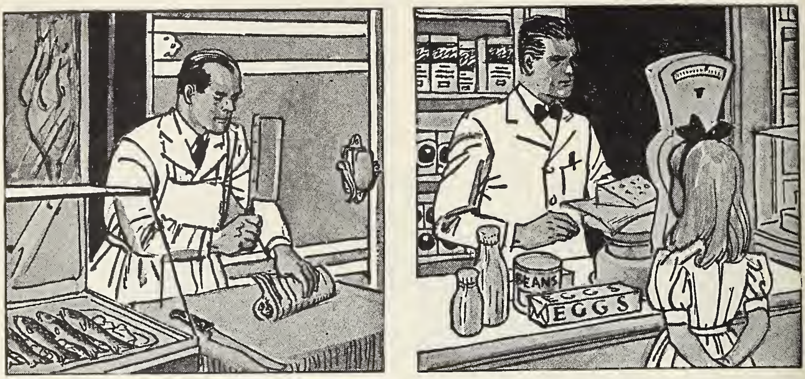
bers of the class agreed in the case of any given result, should you know positively that that result was correct? Explain.

***Values of the different classes of foods.** *Carbohydrates.* The carbohydrate foods—starches and sugars—are cheaper than fats and proteins. Also, they are used more effectively by the body. Common carbohydrate foods are potatoes, bread, fruits, vegetables, and cane sugar. Nearly all the starches and sugars we eat are obtained from plants or their products.

Sugars are a quick source of energy. For this reason athletes frequently eat sugar before engaging in contests. Also, soldiers are given sweets as part of their regular food on long hard marches. If more sugar is eaten than is necessary for the fuel needs of the body, the extra sugar is stored as animal sugar, or glycogen, in the liver and the muscles. This glycogen serves as a reserve store of energy. Additional extra stores of carbohydrates are changed to fats and are stored among the various body tissues. When an animal needs more energy than its food and glycogen will supply directly, these stored fats are used as fuel.

If too great a proportion of carbohydrates is included in the diet, a person may become too fat or may develop diabetes. The daily diet should, however, include one or more vegetables and fruits rich in carbohydrates.

**Fats.* To be properly balanced, the daily diet should contain some fat, such as butter, oleomargarine, or animal fat. Fats are not quickly digested—in fact, the more fat that is eaten with a meal, the more slowly the meal digests. There are great differences also in the lengths of time required to digest various fats. Olive oil and pork fat, for example, are more quickly digested than mutton fat. These statements do not mean, however, that foods



What protein foods are shown in these pictures? How many protein foods can you name?

which are digested quickly are necessarily more valuable than those which require a longer time to digest. The contrary is often true.

Fats are valuable in the diet for several reasons: (1) their high Calorie content makes them valuable in cold countries and in cold weather; (2) they protect the body from rapid loss or gain of heat; and (3) they serve as a cushion to protect delicate organs from shock.

There are some kinds of fats that the body needs which it cannot manufacture from carbohydrates. To secure these fats we must eat plants and animals that produce them.

Proteins. *The most valuable sources of proteins are meats, fish, and animal products, such as eggs, milk, and cheese; but proteins are secured also from beans, peas, nuts, and many other foods obtained from plants. Proteins are a necessary part of every day's diet because they are the only foods which provide material for building and replacing protoplasm. Protoplasm is composed largely of proteins. These in turn are composed of certain compounds called amino acids. Twenty-one different amino acids are known. At least ten of these must be present in the diet if an animal is to remain healthy.

All carbohydrates and fats are composed of carbon, hydrogen, and oxygen in varying proportions, depending on the nature of the sugar, starch, and fat. Proteins are likewise made up of carbon, hydrogen, and oxygen, but in addition all contain nitrogen. Some contain also sulfur, phosphorus, and other elements.

Certain excellent sources of proteins would not serve at all if they were the only protein food eaten. Gelatin, for example, which is made chiefly from bones and cartilage, lacks three of the amino acids which are necessary to protoplasm. Hence, if gelatin were the only source of protein, the body

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A mother zebra and her colt at the Detroit zoo. **Self-test on Scientific Principles:** What advantages do wild zebras probably derive from having striped bodies? State a principle (see page 626) which supports your answer

would waste away. Our diet, therefore, needs to include a wide variety of proteins in order to provide all the amino acids of which our protoplasm is composed. The proteins of meat are somewhat better materials for building human protoplasm than are vegetable proteins.

Proteins, like other food substances, can be transformed into carbohydrates and stored in the body. But most proteins not used in building protoplasm are burned as fuel in the cells.

Milk. The young of all the higher animals eat only milk as food during the earliest parts of their lives. Human babies are often fed from birth upon cow's milk, to which is sometimes added some sugar, water, and perhaps other substances. Cow's milk, however, is usually not so good for them as their own mother's milk.

*Although milk is nearly 90 per cent water, it also contains fats, proteins, and carbohydrates. Moreover, it contains salts of calcium and phosphorus, which are necessary for bone-building. It also contains important vitamins. Milk has an important place in the diet, especially in that of growing children. Milk is, however, deficient in some necessary substances, especially iron. Other foods must be added to the diets of all but very young children.

A Reference Table of the Food Values of an Average Serving of Certain Food Materials[1]

Food	Measure	Calories			Total Calories
		Protein	Fat	Carbo-hydrate	
Apple	½ large	2	3	45	50
Asparagus	4 stalks, 4 in. long	3	1	6	10
Bacon	4–5 small slices	13	87	...	100
Banana	1 medium	4	4	67	75
Beans, dried	¼ cup	45	8	118	171
Beans, lima, dried	¼ cup	42	8	150	200
Beans, lima, fresh	½ cup	23	5	72	100
Beans, string, fresh	⅓ cup	3	1	11	15
Beef, lean, round	2 slices, 4 × 3 × ¼ in.	96	104	...	200
Beets	⅓ cup, cubes	3	1	21	25
Blackberries	½ cup	9	16	75	100
Boston brown bread	½ in. slice, 3 in. diam.	7	6	54	67
Bran, wheat	¼ cup	8	3	43	54
Bread, graham	1 slice, 3¼ × 2 × ⅜ in.	5	2	26	33
Bread, white	1 slice, 3 × 3½ × ½ in.	7	3	40	50
Butter	pat, 1 T.[2]	1	99	...	100
Buttermilk	½ pt.	29	12	48	89
Cabbage, chopped	½ cup	2	1	7	10
Cake, sponge, 2 eggs, hot water	1 piece, 3 × 2¾ × ⅞ in.	11	10	129	150
Cantaloupe	½ melon	3	...	47	50
Carrots, cooked	2 medium	4	2	34	40
Cauliflower	⅕ small head	5	3	12	20
Celery	¼ cup	2	...	4	6
Cheese, American	cube, 1 in.	23	63	3	89
Cheese, cottage	3⅔ T.	49	2	11	62
Cherries, stoned	¼ cup	1	2	22	25
Chicken, roast	1 slice, 4 × 2½ × ¼ in.	51	49	...	100
Corn, canned	⅓ cup	11	11	78	100
Corn, fresh	1 ear, 6 in.	6	4	40	50
Corn meal, cooked	⅔ cup	10	5	85	100
Cream, thin	2 T.	2	43	5	50
Dandelion greens	½ cup	12	11	52	75
Dates, unstoned	3–4	2	7	91	100
Egg white	1	13	1	...	14
Egg, whole	1 egg	25	45	...	70
Egg yolk	1	11	45	...	56
Figs	3 large	10	2	188	200
Fish, lean, broiled	1 slice, 4 × 2¼ × 1 in.	81	52	...	133
Gingerbread, plain	1 piece, 2 × 1⅔ × 2 in.	14	42	144	200
Grapefruit	½ large	7	4	89	100
Grapes, white	22	5	15	80	100
Ham, boiled	1 slice, 4¾ × 6 × ⅛ in.	44	106	...	150
Honey	1 T.[2]	1	...	99	100
Ice cream	⅔ cup	13	202	105	320

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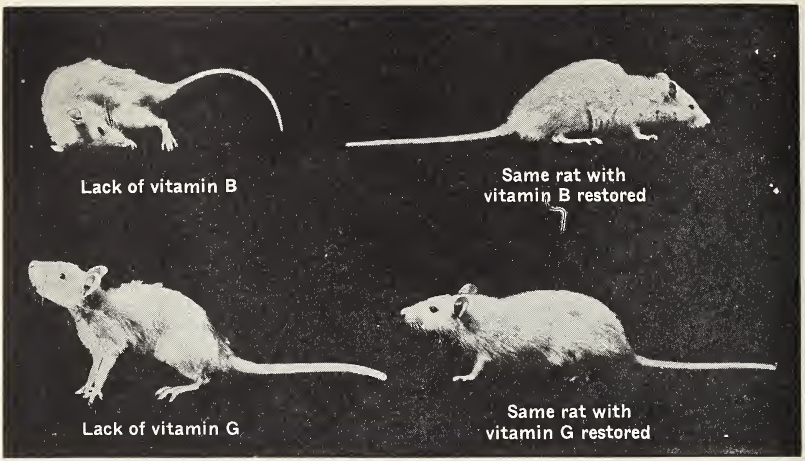
[1] Compiled from various sources: M. S. Rose, *Laboratory Handbook for Dietetics*; M. S. Rose, *Feeding the Family*; H. C. Sherman, *Food Products*; and others.

[2] T. = tablespoonful.

Food	Measure	Calories			Total Calories
		Protein	Fat	Carbo-hydrate	
Lamb chop, broiled	1 chop	40	60	...	100
Lamb, roast	1 slice, 3½ × 4½ × ⅛ in.	41	59	...	100
Lettuce	¼ head	3	2	7	12
Liver, calf's, broiled	medium-sized serving	62	38	...	100
Macaroni, cooked	½ cup	7	1	42	50
Maple sirup	2 T.	...	...	133	133
Milk, whole	½ pt.	34	88	48	170
Molasses	2 T.	4	...	129	133
Mutton, roast	1 slice, 3 × 3¾ × ⅛ in.	33	67	...	100
Oatmeal, cooked	⅔ cup	11	11	45	67
Olive oil	1 T.	...	100	...	100
Olives, green	4 medium	1	41	8	50
Onions	3 to 4 medium	13	6	81	100
Orange	1 medium	5	2	68	75
Orange juice	½ cup	...	...	50	50
Oysters, raw	½ cup	37	18	20	75
Peaches	3 medium	6	3	91	100
Peanuts	20–24 single nuts	19	63	18	100
Peas	⅜ cup	14	2	34	50
Peas, dried	⅜ cup	70	6	177	253
Pecans	12 meats	5	87	8	100
Pineapple	2 slices, 1 in. thick	4	6	90	100
Pork chop, lean	1 chop	64	136	...	200
Potato, sweet	1 medium	12	10	178	200
Potato, white	1 medium	11	1	88	100
Prunes	4 medium	3	...	97	100
Raisins	¼ cup	3	9	88	100
Rhubarb	1 cup	2	7	16	25
Rice, white, steamed	¾ cup	9	1	90	100
Sirup, corn	1¾ T.	...	...	100	100
Spinach, cooked	⅝ cup	3	2	20	25
Squash, cooked	½ cup	4	5	46	55
Strawberries	⅔ cup	5	7	38	50
Sugar	1 T.	...	...	50	50
Tomato, fresh	1 small	4	4	17	25
Turnip, cubes, raw	½ cup	3	1	21	25
Veal leg, lean, broiled	1 serving	105	45	...	150
Walnuts, English	8–16 meats	11	82	7	100

The number of Calories one needs varies not only with one's work but also with age and sex. Thus a child two years of age needs about 900 Calories per day, and this number increases at about the rate of 100 Calories for each year until the child is twelve. Between twelve and fourteen years a girl needs about 2100 Calories per day. A girl of fifteen or sixteen and a boy of thirteen or fourteen need about 2400 Calories. A boy of fifteen or sixteen needs about 2700 Calories. One author states that about one sixth of the Calories should be supplied by proteins, about one fifth by fats, and the rest by carbohydrates. From these facts and those in the table above prepare some daily diets which would serve for boys and girls of various ages, and which would serve for men requiring the number of Calories indicated on pages 315 and 316.


Lack of vitamin B
Same rat with vitamin B restored
Lack of vitamin G
Same rat with vitamin G restored

The results of lack of vitamins B and G. What are the effects of the lack of other vitamins? (Consult a textbook of physiology or an encyclopedia)

Self-test. **1.** Fats furnish (1) half; (2) nearly twice; (3) three times; (4) more than twice; (5) just as many Calories of energy per gram as do carbohydrates or proteins.

2. Which of the following terms does not belong with the rest: (1) grape sugar; (2) proteins; (3) glucose; (4) corn-starch; (5) honey; (6) glycogen; (7) energy; (8) food?

3. If more carbohydrate food is eaten than is needed by the body, the excess is stored in the body as *protein*.

4. Which of the following terms does not belong with the rest: (1) olive oil; (2) cornstarch; (3) lard; (4) butter; (5) tallow; (6) corn oil?

5. Of the foods, only *fats* serve to build and to replace protoplasm.

6. Which of the following terms does not belong with the rest: (1) olive oil; (2) milk; (3) very lean meat; (4) cheese; (5) peanuts; (6) eggs?

WHAT ARE SOME IMPORTANT FACTS WHICH ONE SHOULD KNOW ABOUT THE NON-ENERGY FOODS?

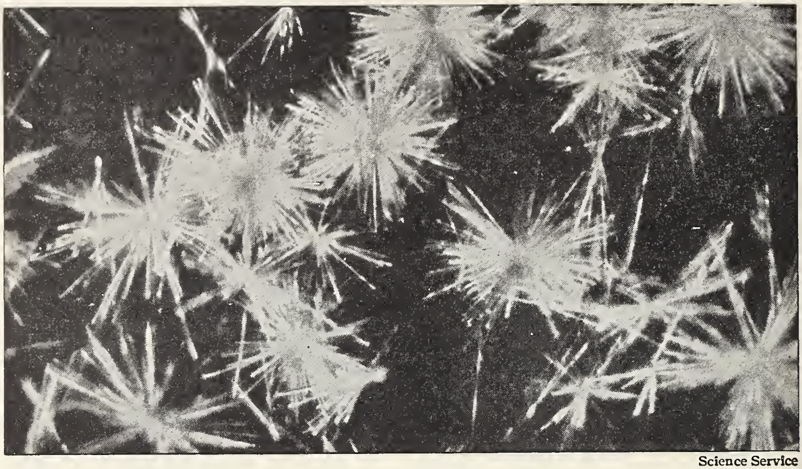
Vitamins. *It has long been known that people who were forced to live for long periods under conditions which were not normal were liable to contract a variety of serious diseases. Soldiers in time of war, people in besieged castles and cities, people in famine countries, and sailors on long voyages often developed diseases which rarely affected people living under ordinary conditions. It was not known until fairly recently, however, that such diseases were "food-deficiency diseases," that is, diseases caused by the lack of certain necessary substances, called vitamins,[1] in the diet.

Vitamins are found in such foods as fresh fruits, whole cereals, and vegetables, and particularly in the internal organs of fish and other animals. Vitamins are necessary not only to prevent food-deficiency diseases, but also to promote good health. The chart that follows shows various ways in which vitamins are valuable to us:

Name of Vitamin	Source	Disease or Condition Controlled	How It Promotes Health
Vitamin A	Butter, eggs, whole milk, green and yellow vegetables	Prevents an eye disease (xerophthalmia) and also "night blindness"	Helps the body to resist infections, aids growth
Vitamin B (thiamin)	Whole grains, eggs, fruits, vegetables	Prevents beriberi	Aids appetite and digestion, promotes growth, and keeps the nerve tissue in a healthy condition
Vitamin C (ascorbic acid)	Citrus fruits, as lemons and oranges; tomatoes; cabbage	Prevents scurvy	Aids development of bones and teeth
Vitamin D (ergosterol)	Milk, cream, fish-liver oils, butter, eggs	Prevents rickets	Aids in development of strong bones and teeth
Vitamin E	Whole grains, vegetables, meat, milk, butter	Prevents sterility in rats; that is, it keeps them able to have young. Value to man not proved	Not known
Vitamin B_2, also known as G (riboflavin)	Milk, eggs, meat (especially liver), green vegetables, yeast	(Not completely determined)	Aids in rate of growth
Vitamin P (nicotinic acid)	Egg yolk, meat, yeast	Prevents pellagra	Maintains the health of the skin and the nervous system

---

[1] When vitamins were first discovered, their chemical compositions were unknown. Therefore, for convenience, as each became known, it was given a letter, "A," "B," "C," etc. During the past few years, however, the exact chemical structures of the various vitamins have been discovered. Consequently the letter names are being displaced by the more precise and accurate chemical names. The letters are used in this book because current reading materials most commonly use them.



Science Service

Crystals of vitamin B. **Special Report:** The "food-deficiency" diseases

Most of the facts we know concerning the effects of vitamins on the body have been obtained from experiments in feeding animals. But until recently there was no actual measure of the amount of a given vitamin contained in a certain food substance. Now many of the vitamins have been separated from the food substances in which they are found. They form crystals which are readily identified. Several of the vitamins can be synthesized, that is, made in the laboratory.

It is interesting to note that one of the sources of vitamin D is the action of the ultraviolet rays of sunshine on the layers of fat under the skin. Ultraviolet rays are light waves which are too short to be seen as colors. In great cities the sunshine sometimes fails to produce such desired action because the great amounts of smoke and dust in the air absorb the ultraviolet rays before they can reach the ground. City dwellers, especially children, do well, therefore, to add to the daily diet cod-liver oil, halibut-liver oil, salmon-liver oil, or viosterol.

Vitamins, with possibly the exception of vitamin D, are of vegetable origin. Yet when eaten by animals they are not destroyed but may be stored for a considerable time in various organs and are passed into milk or eggs. Peoples like the Eskimos, who live for long periods wholly upon meat, secure their vitamins by eating the vital organs, especially the livers, of animals.

Vitamin fads. The importance of vitamins and the consequent interest in them have caused a number of fads. Moreover, a number of commercial

This drawing was made by a high-school student of biology. Can you name other sources of each vitamin than those she has represented?

products have been widely advertised and sold at high prices because they were represented as containing certain necessary vitamins. It is true that some foods contain more of certain vitamins than do others. Yet the vitamins, with the exception of vitamin D, are found so widely distributed and are needed in such small quantities that the ordinary well-rounded diet is likely to furnish all that are needed. A daily diet which includes both fruit and green vegetables of which one at least is raw, will go far toward supplying the needed vitamins.

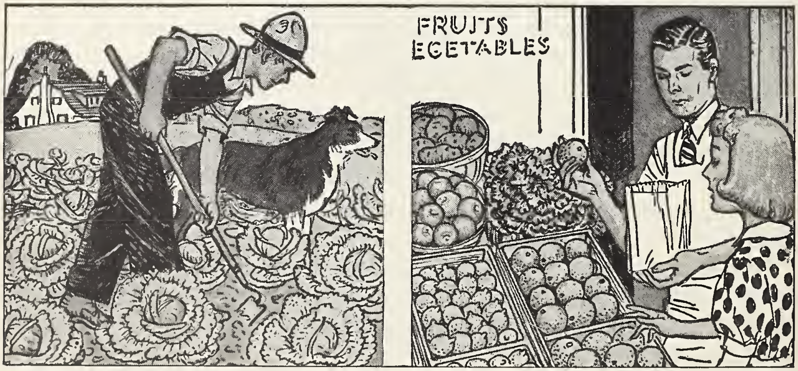
Mineral substances. From 5 to 6 per cent of the weight of the body is due to the mineral matter which it contains. Small quantities of mineral salts are therefore an essential part of the diet. Most of these are in the bones and teeth, but they are also found in other tissues and in the blood. They are chiefly compounds of sodium, potassium, calcium, magnesium, iron, copper, chlorine, phosphorus, sulfur, carbon, fluorine, and iodine. Of these substances, sodium chloride, or common table salt, is the one with which you are probably most familiar.

Animals which eat only flesh usually do not crave salt. Eskimos, who live chiefly on flesh, do not desire salt and will, in fact, reject salty food. The reason is that a straight diet of meat supplies all the salt the body needs. But animals and people living wholly or partly on vegetables find it necessary to eat salt. Animals will travel long distances to secure salt. Recognizing this need, the directors of our national parks place blocks of salt here and there in the woods for the deer to lick. Certain tribes of Africa consider salt so valuable that they use it for money with which to buy wives, cattle, and other possessions.

Salt has an added value as a condiment, since it gives a pleasant flavor to foods and therefore stimulates the flow of digestive juices. Most people, however, use considerably more salt than they need. There is a possibility of harm from using too much salt.

The body needs and uses inorganic salts other than table salt in considerable variety. Ordinary foods contain a sufficient supply of these salts. Drinking water also is a source of some needed minerals. Calcium is the mineral which is most likely not to be present in sufficient quantities in the diet. Sufficient quantities of calcium salts are needed to produce healthy bones and teeth. These salts also have an important function in connection with the irritability of muscles and nerves. Poi, a food made in the Hawaiian Islands from taro root, is exceptionally rich in calcium salts. People who make poi a part of the regular diet have well-developed bone structure and good teeth. Bread and milk are also rich in these salts.

The body requires certain compounds of iron. These compounds are necessary in forming red blood cells. Anemia is a serious disease, which is due in part to lack of iron salts in the body. Certain mild forms can often be cured by changing the diet to include foods rich in iron salts, such as liver, spinach, yolk of egg, asparagus, prunes, beef, cabbage (the green leaves), and apples. Goiter, a serious and sometimes fatal disease which is accompanied by an enlargement of a certain gland (thyroid) in the neck, is often caused by lack of iodine salts in the diet.



What foods containing minerals are shown in these pictures? How many other foods containing minerals can you name?

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Sheep on a Wyoming ranch. Sheep and goats can get along for a long time without drinking; some desert animals never drink at all. From which of the sources of water mentioned in the text must these animals receive the water they need?

Water. *Since protoplasm consists largely of water, no organism can exist long without new supplies. Water is necessary to the body in several ways: (1) to supply and renew the amounts needed in the tissues; (2) to dissolve various food substances, waste substances, and other chemical compounds in the body; (3) to transport substances within the body—for example, foods and waste materials through the digestive system, and digested foods, oxygen, carbon dioxide, and other substances through the blood stream.

The body gets rid of water through the action of the kidneys, of the sweat glands, and of the lungs. The losses of water in the body must be made up in some way. Part of this necessary water is replaced (1) by the food we eat, since no food is entirely lacking in water and since the green-vegetable foods are mostly water, and (2) by the water which results from the burning of the fuel in the body. If the water secured from these sources is not sufficient, additional water must be drunk.

It is not unusual to find among rules of health a statement to the effect that everybody should drink at least six glasses of water every day. This statement may possibly be true of people on the average, but is not necessarily true for every person. One's needs for water vary from day to day, depending on the food one eats, the amount of exercise one takes, and upon weather conditions—temperature, humidity (that is, moisture in the air), and the like. Whenever our bodies need additional water, we become thirsty and remain thirsty until we have drunk the amount needed by the body. Some water with our meals is probably of benefit. But food should be sufficiently chewed so that it can be easily swallowed without the need of washing it down with water.

Food flavors and condiments. Much of the value of our food is derived from its odor, flavor, and appearance. The sight of attractive food causes the mouth to water; that is, it starts a flow of saliva.[1] Moreover, the tempting odors and flavors of foods during eating stimulate the flow of digestive juices in the stomach. Condiments, such as mustard, horse-radish, pepper, and other spices, are used in wide variety in civilized countries for the sake of improving the flavor of foods.

Stimulants. Coffee, tea, and cocoa or chocolate contain substances which are nerve stimulants. When taken moderately they reduce both mental and physical fatigue. Thus they make it possible for one to continue mental work for longer periods than without them. If used moderately, neither coffee nor tea is likely to be harmful to adults. It is better, however, for young people to drink liquids that have some food value, as milk and milk drinks. Neither tea nor coffee, however, is dangerous in the sense that alcohol is dangerous.

Diet and health. Many people eat far more food than they need. As a result, their digestive organs may be overworked or actually injured. In contrast, there are millions who are suffering from malnutrition, that is, insufficient nutrition either because they do not have enough food or because they do not have the right kinds of food. Because of malnutrition there are many people who have barely enough energy to exist; there are little children who cannot develop properly and who are never really healthy; and there are many thousands of people who have bad teeth. Improved nutrition in many of these cases demands that the diets be extended to include more milk, fruits, and vegetables.[2]

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[1] *Saliva* (sȧ lī′vȧ): a digestive juice in the mouth.

[2] To The Teacher. If it seems desirable at this point to consider additional relations of food to health, material will be found in Chapter XXVI.

Armstrong Roberts

Plan a well-balanced picnic meal. (Consult the table, pp. 322 and 323). How would such a meal differ from an ordinary meal eaten at home?

Economy in foods. Good, nourishing food need not be expensive. Most people are likely to pay more for foods than is necessary. It is a fortunate fact that many of the cheapest foods are among the most nourishing. The cheaper cuts of meats, for example, are as nourishing as more expensive cuts. Cheese and eggs will often supply needed proteins at a cost below that of meat. Furthermore, cheese and eggs contain vitamins which do not exist in most cuts of meat.

In foods the cost per pound does not always indicate the true relative cost. Certain cuts of meat, for example, which may cost little per pound may be relatively expensive because they contain so much waste in cartilage and bone. Other foods may be expensive, though low in price, because they contain such large proportions of water.

Self-test. 1. Five different classes of non-energy foods are (1) --?--, (2) --?--, (3) --?--, (4) --?--, and (5) --?--.

2. Fresh fruits are valuable in the diet as a source of *proteins.*

3. Milk and eggs are valuable sources not only of energy but also of *Calories.*

4. Two cheap and common sources of bone-building minerals are --?-- and --?--.

5. A disease which can sometimes be cured by eating foods rich in iron salts is --?--.

6. Name three purposes served by water in the body.

7. In general, tea and coffee are not harmful to *children.*

8. A food which is both a stimulant and an energy food is *tea.*

9. Four mineral salts necessary to the body are compounds of (1) --?--, (2) --?--, (3) --?--, and (4) --?--.

Self-test on Organization of Facts. Make a complete outline listing the classes of foods, somewhat in this manner:

Foods

- I. Essential foods
  - *A.*
    - 1.
    - 2.
    - Etc.
  - *B.*
    - 1.
    - Etc.
- II.
  - *A.*
    - Etc.

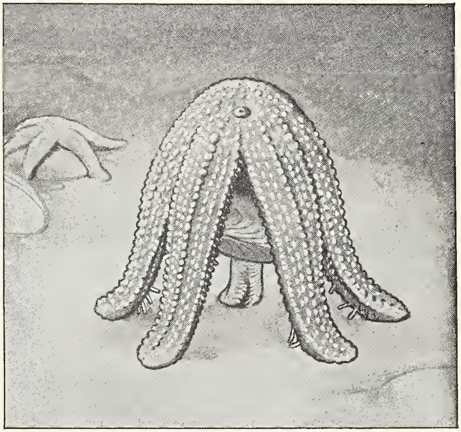
Self-test on Important Biological Terms

carbohydrate
digestive
fat
nutrient
protein
rudimentary
vitamin

Self-test on Biological Principles. 1. How do the food-getting habits of the sponge illustrate the beginnings of division of labor?

2. What facts can you state from this chapter which seem to prove this principle: "In general, the more complex an animal is, the more complex are its food-getting structures."

Self-test on Making Comparisons (see "How to Study," p. x). **1.** The starfish feeds mostly on such animals as the clam and the oyster. It crawls about until it finds a victim. Then, bending its arms down around the shell, it fastens its tube feet to the two halves of the shell. The starfish, by straightening out its arms, slowly begins to pull the two halves of the shell apart. Since the starfish can depend on water pressure to hold its tube feet against the shell, it never seems to get tired. But the oyster does. In twenty or thirty minutes the oyster becomes too tired to continue the unequal struggle longer. Its shell is slowly pulled open, and the helpless oyster is now ready to be eaten. But the mouth of the starfish is small. The oyster is too large to go into it. How will the starfish manage to get the oyster into its mouth? The answer is, it does not. Since food cannot be taken into the stomach, as in most animals, the stomach goes out to the food. The starfish forces its stomach out through its mouth and wraps it around the oyster. Digestive juices are poured out which reduce the oyster to a liquid, so that it can be absorbed by the stomach. When the oyster has all been digested and absorbed, the stomach is drawn back by the muscles which fasten it into each arm, and the starfish goes on its way again. Compare the means by which starfish secure food with those of the other animals discussed in this chapter.


Starfish opening an oyster. To which of the types of enemies listed on page 58 does the starfish belong?

2. Recall what materials the roots of green plants absorb from the soil, and how they absorb these materials. How are the materials and the processes like and how are they different from those of the dependent plants?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Honey is an organic product used as food by certain animals. Can you name other organic products which serve as food?

2. Can you explain how the water pressure helps to hold the tube feet of the starfish against the oyster shell?

3. List the common snakes you know which you have observed to eat insects; to eat birds; to eat other snakes; to eat amphibians, such as frogs, toads, or salamanders; to eat small rodents, such as field mice, rats, or gophers.

4. What other types of bird beaks (than those mentioned in the text) do you know? How do they especially fit each bird for the sort of food it eats?

5. List the common birds you know which you have observed to eat insects; to eat carrion, or decaying flesh; to eat seeds; to eat fruit; to eat other birds; to eat small mammals.

6. Can you give one or more examples of each of the parts of plants which were named as being used as food?

7. How many carbohydrate foods can you list in five minutes?

8. Why is a diet exclusively of milk not a good one to follow?

9. How many fatty foods can you name in five minutes? Why do people living in cold climates eat more fat than those living in the tropics? What advantages do animals such as seals, walruses, and whales derive from having thick layers of fat under their skins?

10. How many of the animals discussed in this chapter move about seeking or hunting for food? How many remain in one spot, merely absorbing or capturing what comes near? How many other animals can you name which belong in the two classes indicated in these questions?

11. In which of the three ways enumerated on page 329 is water used by plants?

Exercises on Scientific Method. 1. *Constructing a Hypothesis.* A hypothesis is an attempt to make a reasonable explanation of facts or to make a prediction of how or why something happens or is done. Can you make a hypothesis which may explain how an earthworm can get food into its mouth? Here are some necessary facts upon which to base your hypothesis: The earthworm has a mouth with no teeth. It is able to expand and contract the walls of the cavity behind its mouth (see figure p. 341). The earthworm pushes its mouth against the soil so tightly that no air can enter its mouth. It then increases the size of the cavity behind its mouth. Soil enters its mouth. Why?

2. *Making Inferences.* What sort of food does a caterpillar eat? What does a butterfly eat? What change, then, must occur in the type of mouth during the pupa stage?

Exercise on Scientific Attitudes. The history of the use of gelatin as a food illustrates well how scientific knowledge grows. Because gelatin was found to be both rich in nitrogen and easily soluble, scientists thought that it would prove to be an unusually nourishing food. During the French Revolution (1789–1795) a committee investigated the nourishing qualities of gelatin. Its report was favorable, as was also that of a later commission from the French Academy in 1814. On the basis of this latter report gelatin came to be largely used as nourishing food in hospitals. It proved so unsatisfactory, however, that doubts arose concerning its value as a nutrient. Accordingly a second gelatin commission was appointed by the French

Academy (1841), another by the Netherlands Institute (1844), and still another by the Academy of Medicine in Paris (1850). These three commissions reversed the opinions announced by the earlier scientific commissions. All three independently reported that gelatin has no value as nourishment, and that it is harmful rather than beneficial as a food. Later experiments, however, determined the fact that while gelatin lacks certain amino acids, without which the body cannot repair tissue, nevertheless it possesses certain food values. Which of the scientific attitudes (p. 624) are illustrated by this story?

Special Reports. 1. How is milk pasteurized in a modern dairy? What are the conditions which a dairy must meet in order that its product may be marketed as "Certified Milk"? as "Grade A Milk"? What is meant by "tuberculin-tested cows"?

2. What are the characteristics of scurvy, beriberi, pellagra, rickets? In what parts of the world are these diseases most common? Why have deficiency diseases been especially widespread and serious during the Second World War in Greece, Yugoslavia, and other countries conquered by the Axis?

3. During the Second World War one ship carrying meats, vegetables, eggs, milk, and many other kinds of goods from the United States and Canada to their allies was able to carry as much of these foods as nine ships of the same size during the First World War. This was possible because the food was dehydrated. What is dehydrated food? How are foods dehydrated? How do dehydrated foods compare with fresh foods with respect to their food values and flavors?

4. Victory Gardens were important in the First World War, but were even more important in the Second World War, as a necessary means of increasing the country's food supplies. Make a plan for an average family of a Victory Garden, about 40 feet long and 60 feet wide. Indicate how many rows of each of the various kinds of vegetables you would be able to plant in this garden. Show the distances between the various rows. Make a chart to indicate when each kind of vegetable would need to be planted and when you could expect each vegetable to be ready to eat. Garden magazines, seed catalogues, and bulletins from the Department of Agriculture will supply the information you need in making your garden plan.

5. During the Second World War our soldiers in the jungles and other places where they were more or less on their own resources carried their individual rations. Find out the nature and quantity of each kind of food the soldiers carried. Explain how together these foods constitute a completely balanced diet.

6. In what ways does war affect agriculture? What steps must and can be taken to restore agriculture in the postwar period?

CHAPTER XVI

Preparing Food for Use by Protoplasm (Digestion)

Questions This Chapter Answers. 1. Why is digestion of food necessary? · 2. What is digestion? · 3. What is the function of enzymes? · 4. How is digestion carried on in plants? · 5. How is digestion carried on in typical animals? · 6. What digestive functions are performed by the mouth? · 7. What functions are performed by the stomach? by the small intestine? by the large intestine?

WHAT IS THE NATURE OF DIGESTION?

Why food must be digested. A fish would not serve as nourishment for a larger fish, a sea gull, a cat, or a man just as it is when caught. A loaf of bread, just as it is baked, would be of no more use as nourishment than a rock of the same size and shape unless it could somehow be changed so that the body could use it. The reasons for these statements are that (1) only foods in liquid form can be taken into living cells, and (2) only foods that have been reduced to simpler compounds can be used by cells as food. Therefore nutrient, or energy, foods—carbohydrates, proteins, and fats—must all be changed by the organism so that they can be absorbed and later used by the various cells and tissues. The non-energy foods which the body uses are absorbed in the form in which they are eaten.

*The term *digestion* is used to include all the processes by which any food substance is changed to simpler compounds that can be used by the cells as sources of energy or of materials for building protoplasm. Digestion includes both physical and chemical changes.

Enzymes. There are many substances found in the study of chemistry which affect the speed of chemical processes without themselves taking part in it. In the study of plant and animal digestion we find a great number of such substances, called enzymes. Enzymes are necessary to digestion in every animal and plant. They cause the food substances to undergo necessary chemical changes. The enzymes themselves do not combine with the food or undergo changes of any sort. A small amount of an enzyme, therefore, can bring about the digestion of a great amount of food. Moreover, the enzyme can continue to act for an indefinite time.

Enzymes are very complex organic compounds. It is believed that many, if not all, of them are proteins. Each one which aids in digestion is effective in hastening a certain part of the digestive process, and is effective in no other process. Enzymes are most effective at about 40° C to 50° C. They have no effect at the freezing temperature of water or at its boiling point. At the latter temperature they are totally destroyed—in fact, most of them are destroyed at 60° C.

Acme

Stimulating the team. Can you think of ways in which the cheering section, with its school colors and school yells, has a function with respect to the team's action somewhat similar to that of an enzyme with respect to digestion?

Self-test. **1.** Only the *energy* foods require to be digested.

2. A substance which causes the digestion of foods without itself being changed is called a *vitamin*.

3. Before the body can use food, the food must undergo physical and chemical changes which together make up the process of --?--.

4. Anything like ice water is likely to *increase* the speed of digestion. Explain this statement as you think it should be made.

HOW DO THE DIGESTIVE SYSTEMS OF THE LOWER ORGANISMS DIFFER FROM THOSE OF THE HIGHER ORGANISMS?

Digestion in plants. The simplest plants, such as the bacteria, do not carry on digestion within the cell. The cell secretes enzymes which pass out through the cell wall and digest the food material outside. The digested food is then absorbed into the cell by the process of osmosis.

Galloway

Gathering sap from sugar-maple trees in New England. **Self-test on Mastery of Facts:** Explain the processes that take place in the tree as a result of which men are able to secure the sap from which maple sugar is made. You may wish to review Unit II

Experiment 44. Does digestion take place—that is, is starch changed to sugar—in germinating seeds? Germinate some bean seeds or corn seeds in sphagnum moss or in moist sawdust. Grind some of the germinated seeds and also some dry seeds of the same kind for a control. Test a sample of each both for starch and for sugar (see Experiment 43, p. 317). Answer with a complete statement the question asked at the beginning of this experiment.

Experiment 45. Does diastase digest starch, that is, change it to sugar? Into a test tube put a little starch. Add warm water and a little diastase. Into a second test tube put an equal quantity of starch and warm water but no diastase. Keep the test tubes side by side in a warm place for an hour. Test the contents of each for both starch and sugar. State your conclusions in a complete sentence or two.

What was the control in this experiment (see "Elements of Scientific Method," page 625)? Why was it used? Can you explain why the presence of diastase was the experimental factor (see the Glossary)?

In green plants, starch is manufactured by photosynthesis in every cell containing chlorophyll. The starch, however, is insoluble. Hence it cannot be used directly as food by the plant. The starch must therefore be changed into some other substance which is soluble. Through the action of an enzyme (diastase) the molecules of starch are changed to molecules of sugar. These dissolve in water and pass readily through the cell walls of the plant. The sugar finds its way from the cells into the sap and is circulated throughout the plant. It passes into the living parts and furnishes nourishment to each cell. The surplus sugar, which is not used in the living cells, may again be changed into starch and stored in the plant for future use.

When the plant needs to draw upon its reserve food supplies, this stored food must be digested a second time. Thus it again becomes soluble in the sap and may be carried to the parts where it is needed. The starches, proteins, and fats, therefore, are digested by plant enzymes (respectively diastase, protease, and lipase). Probably every active plant cell secretes enzymes of one sort or another.

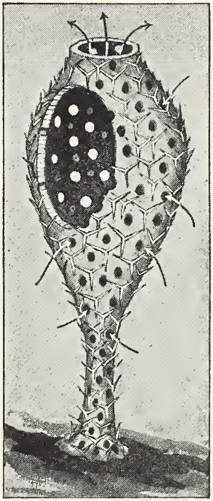
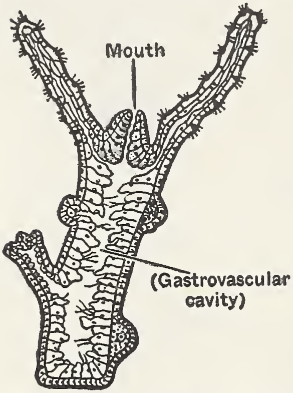


Diagram of a simple sponge. In this figure a portion of the wall is cut away to show the structure. To what extent is digestion of food in the sponge like that in *Amoeba*?

Digestion in simple animals. In the lowest forms of animal life, as in the lowest plants, the process of digestion is very simple. With the one-celled animals the food is attacked by enzymes and digestion takes place within the cell.

Many of the simpler Metazoa, such as the sponge, have no special digestive organs. In these animals, therefore, digestion is accomplished by special cells. In the sponge, for example, the food is captured and digested mostly by the cells around the openings of the many pores. Each of these food-getting cells acts as if it were a separate organism in so far as securing and digesting food is concerned. The cells which are able to capture and digest food furnish the digested food needed by all those which cannot do the work of digestion.

Hydra has very simple digestive organs. It has a mouth and a crude stomach (the gastrovascular cavity). Most of its food is digested in this cavity by enzymes secreted by the cells of the inside layer (the endoderm layer). The rest of its food is captured and digested by enzymes in the separate cells in much the same way as in *Amoeba*.

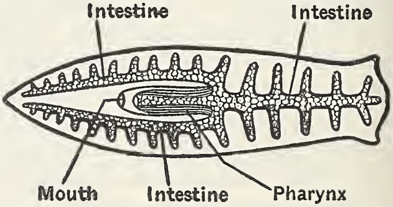


In what two regions does *Hydra* digest food?

Animals higher in the scale of life than *Hydra* have special organs of digestion. In certain of the flatworms there is not only a mouth but also a simple intestine. In both *Hydra* and the flatworm, however, the food cavity has only one opening, the mouth. Therefore the undigested food and the body wastes are discharged through this opening.

Digestion in higher animals. A study of a more complex animal, such as the earthworm, reveals a still more complex digestive system. It includes an esophagus,[1] leading from the mouth, a crop for food storage, a gizzard for grinding the food, a straight intestine and special organs, called glands, for producing enzymes. The intestine has two openings, the mouth and the anus. Waste materials are discharged through the anus. Most of digestion takes place in the intestine.

The processes of digestion in the earthworm are much like those in the higher animals. Indeed, it is believed that the enzymes which accomplish digestion in the earthworm and the final substances into which the food is changed by the processes of digestion are largely the same as those in the digestive system of man.



The flatworm has primitive digestive organs. Can you recall other flatworms which can use only food that is already digested?

The crayfish has jaws and teeth for biting, holding, and crushing food. Its digestive system consists of several organs, each of which secretes enzymes that aid in digestion.

Insects, such as the grasshopper, have still more highly developed digestive organs, similar to those of higher animals. These organs include an intestine

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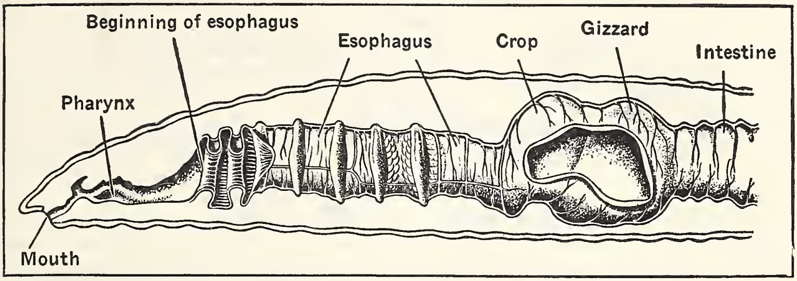
[1] *Esophagus* (ē sŏf'ȧ gŭs): the gullet, that is, the tube through which food and drink pass from the mouth to the stomach.



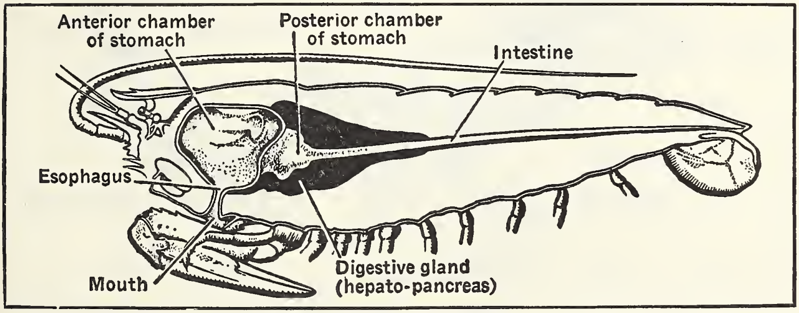
The digestive system of an earthworm. In what respects is the digestive system of the earthworm more complex than the digestive system of the flatworm?

which is slightly coiled, and a large intestine, where wastes are stored before elimination (see the Glossary).

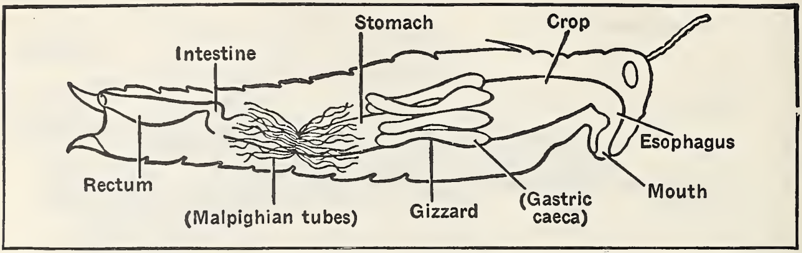
The digestive systems of chordates are much alike. Therefore the digestive system of man, a typical chordate, will be discussed in the next section.

Summary. *From the preceding paragraphs it will be seen that the simpler plants and animals have each a very simple apparatus which serves its needs for digesting foods. A more complex organism, however, has need of a digestive apparatus which is more complex. The organism can survive only if its digestive system, like all its other parts and systems, is adapted to its general structure, its food, and other factors. The higher in the scale of life an organism is, the more nearly its digestive system resembles that of the higher animals, and the less nearly its digestive system resembles that of the simplest animals.

Self-test on Organization of Facts. Various animals were used in this problem to illustrate the increasing complexity of the digestive systems from the lowest to


Anterior chamber of stomach
Posterior chamber of stomach
Intestine
Esophagus
Mouth
Digestive gland (hepato-pancreas)

The digestive system of the crayfish. In what respects is the digestive system of the crayfish more complex than that of the earthworm?



The digestive system of a grasshopper. What organs of digestion do both the grasshopper and the earthworm have? Has either any digestive organs which the other has not?

the highest animals. Can you name the animal used to illustrate each stage listed below, and can you name also the phylum to which each belongs (you may need to review briefly Unit III)?

1. Simple osmosis; no special structure; no division of labor.

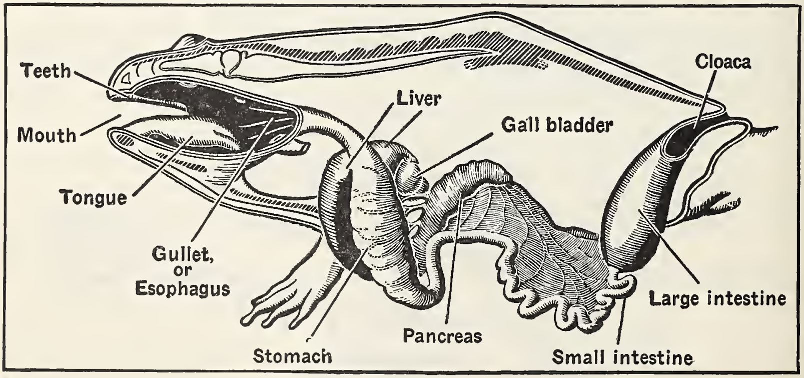
2. The beginnings of division of labor; some cells digesting food for others.

3. A mouth and a very primitive digestive cavity.

4. A simple intestine, having only one opening but digesting part of the food of the animal.

5. A fairly complex food tube, having two openings, having various parts and compartments for different purposes, and having also glands making digestive juices.

6. A more complex food tube, having a coiled intestine, where digestion takes place, and a large intestine.



Digestive system of the frog. Compare the digestive system of the frog with that of man (p. 344). Why would one expect the digestive system of man to be more like that of a frog than that of a grasshopper?

Self-test. 1. In the bacteria *part of the* digestion takes place *inside* the cell.

2. Before plants can use starch as food, it must be changed by *vitamins* into *protein.*

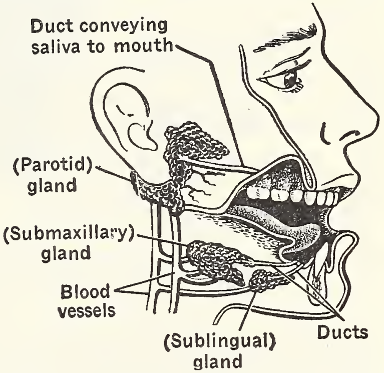
3. Sugar in plants is changed by *protoplasm* before it can be stored as fats, proteins, and --?--.

4. *Certain* Protozoa have special digestive organs.

5. *Few* plants and *most* animals have enzymes which accomplish digestion.

WHAT ARE THE FIRST STAGES OF DIGESTION IN MAN?

Digestion in the mouth. In man digestion starts at the beginning of the alimentary canal and continues throughout almost the entire canal. Digestion, therefore, begins in the mouth. The teeth serve to cut and grind food into small bits. Also, the food is mixed with saliva as it is chewed. Saliva is secreted by three sets of glands. Two of these glands are under the tongue (the sublingual glands); two are on the inner sides of the lower jaw, one on each side (the submaxillary glands); and two are just in front of the ears, one in front of each ear (the parotid glands). The saliva manufactured by these glands is poured into the mouth through ducts, or small tubes. During the process of chewing, the amount of saliva which these six glands pour into the mouth is increased.



The locations of the salivary glands. What advantage is derived from having three pairs of salivary glands at different locations in the mouth, that would probably not be derived from having a single large gland?

*Saliva serves three functions: (1) It softens and moistens the food so that it can be swallowed and so that it will pass down the esophagus. (2) It dissolves dry and solid food so that some of this food in solution finds its way into little pits in the tongue in which the taste buds, or organs of taste, are found. The flavor of the food, if it is pleasant, causes a more plentiful flow of digestive juices in the stomach. (3) It digests starch through the action of an enzyme (ptyalin). The change which this enzyme makes in starch can be discovered by a simple experiment.

Experiment 46. What changes does saliva bring about in starch? Put into your mouth a little corn-starch. Can you note any change in the flavor of the food after it

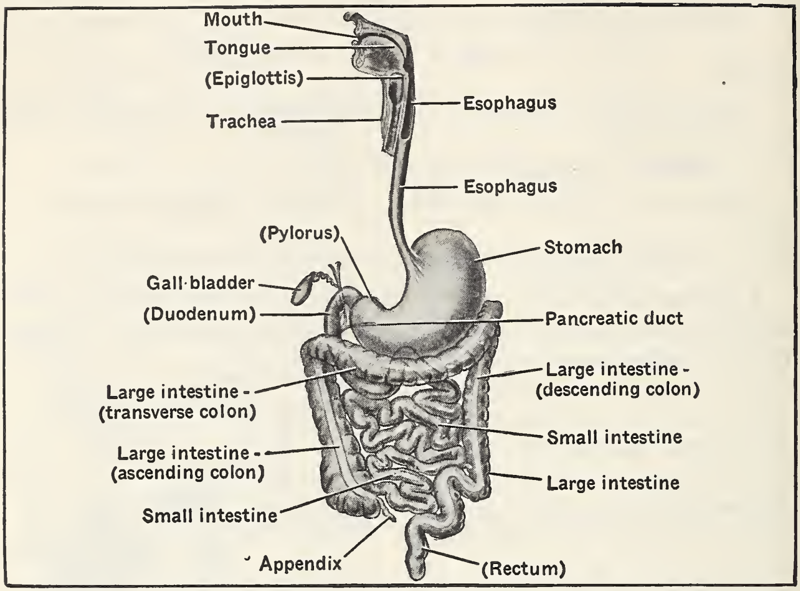


Diagram of the human alimentary canal. Food within the alimentary canal is not considered to be within the body. Explain

has been in the mouth a short time (few seconds)? Now remove the starch and the saliva, placing part in each of two test tubes. Put a little fresh starch mixed with a little warm water into another test tube for a control. Test the contents of the first test tube for starch and of the second for sugar (see page 317). Test the control likewise for sugar. What chemical change has the enzyme (ptyalin) in the saliva effected in the starch?

This experiment illustrates isolating the experimental factor as well as using controls. What conditions or factors were the same in all three test tubes? What factor in the test tubes containing starch and saliva was not present in the control? This was the experimental factor. Why was the control necessary in this experiment?

The throat and esophagus. Swallowing is started by the action of the tongue. It presses against the teeth in front and then arches up against the hard palate in the roof of the mouth. Thus it pushes the food backward and forces it into the throat. Here muscles force the food downward. At the same time the action of other muscles closes the openings into the nose and into the windpipe, or trachea. Occasionally, however, the trachea remains open when food is swallowed, with the result that some of the food enters it, causing the person to choke or even to strangle in an effort to force the food out. The muscles involved in swallowing are involuntary muscles; that is, they cannot be controlled by the will. No matter how strongly one might wish to prevent their action, one could not do so.

Like the mouth and the throat, the esophagus is lined with mucous membrane.[1] In this are an enormous number of microscopic glands that secrete a special fluid, called mucus.[2] Mucus gives a slippery coating to the smooth surface of the esophagus.

The esophagus has two sets of muscles, one set running lengthwise and the other in rings around it. These sets of muscles alternately contract and relax in such a way that a series of wave-like movements passes down the esophagus. These movements force the food downward in much the same way as an object might be forced downward through a rubber hose if a metal ring somewhat smaller than the hose and just behind the object were pulled downward. These wave-like contractions are known as peristaltic waves. They are regular and proceed down the esophagus, one after another. Together they constitute *peristalsis*. Peristalsis occurs throughout the length of the alimentary canal. This process will be explained more fully later.

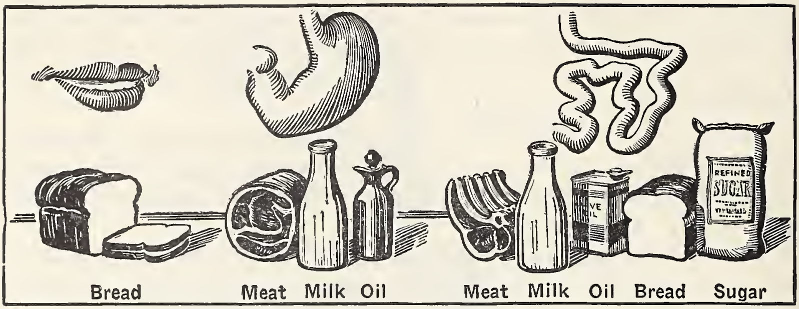
No digestion takes place in the esophagus, except that the enzyme (ptyalin) from the saliva may continue to change starch into sugar. No enzymes are secreted in the esophagus.

Digestion in the stomach. The lower end of the esophagus expands to form the stomach. This is a bag-like organ in which the food is held while it undergoes further digestive action. The stomach is full if it contains any food whatever. It never contains any empty space, because it expands when food enters it and contracts into loose folds like an empty pouch as the food is digested.

Experiment 47. Which is more effective in digesting protein: water, hydrochloric acid, pepsin, or a combination of water, pepsin, and hydrochloric acid? Into each of four test tubes place an equal small quantity of the white of hard-boiled egg. To the first test tube add water enough to fill it about a fourth full. Dissolve pepsin in water and add to the contents of the second tube. Into the third test tube pour water to which you have added a few drops of hydrochloric acid. To the fourth add some of the solution of pepsin in water to which you have added also a few drops of hydrochloric acid. Have the liquids at the same level in all four tubes. Place all four test tubes side by side where they will keep warm but will not become hot. Examine the contents of the tubes every hour or so during the day and again the

[1] *Membrane* (mĕm'brān): a thin soft tissue. *Mucous membrane* (mū'kŭs mĕm'brān): tissue which lines the alimentary canal and the organs concerned with breathing.

[2] See the Glossary.



This picture indicates foods that are digested in the mouth, the stomach, and the intestine. Name the classes of energy foods digested in each of these organs

following day. Summarize the results of the experiment. Answer in a brief paragraph the question asked at the beginning of this experiment.

Like digestion in the mouth, digestion in the stomach includes both physical and chemical changes. Thus the food is not only changed in form and state, but it is also changed in chemical composition.

Soon after food enters the stomach, peristalsis begins. Peristaltic waves start at the middle of the stomach and proceed to the lower end. Digestion by the gastric[1] juice in the stomach proceeds mostly in the lower part. The food remains stored in the upper part. It moves down slowly to take the place of the food in the lower part as this food is first changed to a liquid and is then forced out of the stomach (through the pylorus). The digestion of starch by the enzyme (ptyalin) of the saliva continues until the food reaches the middle of the stomach. Here it becomes mixed with the acid in the gastric juice. The acid stops the digestion of starch for the time being. The changing of starch to sugar, however, is resumed later in the small intestine.

If one were to examine the interior of the stomach, one would see innumerable small pits which mark the mouths of tube-like glands. It is estimated that the stomach contains more than two million of these glands. These are the gastric glands, of which there are several kinds. Each kind secretes a substance necessary to digestion. All these secretions together make up the gastric juice. The gastric juice contains four important substances: hydrochloric acid and three enzymes (pepsin, rennin, and gastric lipase).

The hydrochloric acid performs several functions, among which are these: (1) it softens tissues of the food; (2) it kills bacteria of decay and therefore stops decay of the food; (3) it makes the protein ready for further digestive action.

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[1] *Gastric* (găs′trĭk): having to do with the stomach.

*Each gastric enzyme has a special function. One (pepsin) changes the proteins into simpler substances that are soluble in water. The second (rennin) attacks milk, causing it to curdle. The curdling of milk is a necessary step in its digestion. The third enzyme (lipase) attacks the fats to a slight extent, thus beginning their digestion.

The food in the lower end of the stomach is slowly changed into liquid form by mechanical and chemical action. At the extreme end of the stomach there is an opening (pylorus) which is regulated by a ring of muscle. This muscle relaxes at intervals. As often as it does so, the peristaltic movements, which are occurring regularly, force a little of the liquid food (called chyme) through the opening into the small intestine. The food, although liquid, is not yet completely digested. Only part of it is ready to be absorbed by the body. The rest must undergo further chemical changes in the small intestine.

Self-test. **1.** The three sets of glands that secrete saliva into the human mouth are located --?--, --?--, and --?--.

2. The three functions of saliva are --?--, --?--, and --?--.

3. Food is forced along through the alimentary canal by means of rhythmic waves called *protoplasmic* waves.

4. The enzyme in saliva changes *protein* to *starch.*

5. The three functions which are performed by the hydrochloric acid in the stomach are --?--, --?--, and --?--.

6. The gastric enzymes start the digestion of *starch* and *proteins.*

7. The digestion of *fats* is stopped in the stomach.

HOW IS DIGESTION COMPLETED IN THE INTESTINE?

Digestion in the small intestine. The small intestine is the portion of the alimentary canal which is between the lower end of the stomach and the beginning of the large intestine. It is about twenty feet long. Some experiments will help you to understand the digestive processes which take place in the small intestine.

Experiment 48. Which is more effective in making fat into an emulsion[1]: water, some alkali, such as lye or ammonia, or some acid, such as vinegar or lemon juice? Put into each of three test tubes a half-dozen drops of olive oil, corn oil, or cottonseed oil. To the first add warm water. To the second add warm water in which a little lye or ammonia has been dissolved. To the third add warm water to which a little vinegar or lemon juice has been added. Have equal amounts of liquid in all three test tubes. Allow all three test tubes to stand side by side. Shake the contents of the test tubes from time to time. On the following day examine the contents of all three test tubes. Answer with a complete statement the question asked at the beginning of this experiment.

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[1] *Emulsion* (ē mŭl'shŭn): a liquid containing fat distributed all through it in very fine drops.

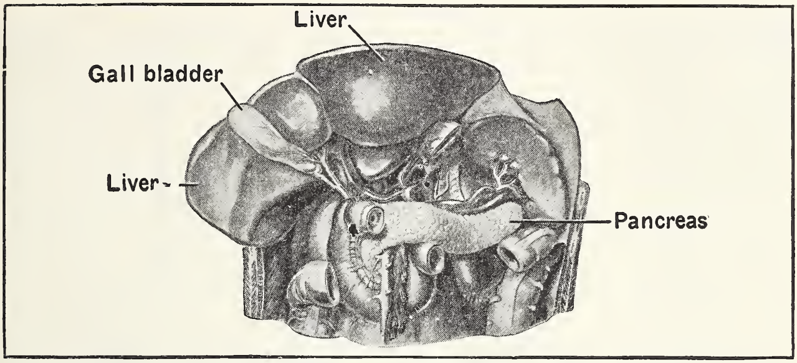
Experiment 49. What is the action of pancreatic juice on fat, protein, and starch? Make some artificial pancreatic juice by adding to 100 cubic centimeters of warm water 1 gram of commercial pancreatin and 2 grams of baking soda. Into each of two test tubes put a few drops of the oil which you made into an emulsion in Experiment 48. Into each of two other test tubes put a small amount of white of egg which has been cut into very small pieces. Into each of two more put a pinch of starch. To the first test tube in each pair add the pancreatic juice and to the second tube of each pair add warm water. Put all six test tubes together in a warm place (70°–80° F). Compare the appearance of each pair of test tubes every day for several days. Summarize the results of your experiment in a few complete sentences.

These experiments illustrate two important elements of scientific method, using controls and isolating the experimental factor. Why was each test tube in Experiments 48 and 49 a control for the others? What substance was common to all the test tubes in each experiment? How many factors or conditions were the same for all test tubes in each experiment? What single factor was different in the test tubes in each experiment? This was the experimental factor.

*The small intestine serves two important functions: (1) it completes the digestion of all the nutrients, and (2) it absorbs the digested foods through its walls into the blood stream. Its great length, its thin walls, and certain structures called villi make possible the absorption of digested food.

Partly digested food (chyme) from the stomach is subjected to the action of three distinct digestive juices in the small intestine: (1) the pancreatic juice, secreted by the pancreas; (2) the bile, secreted by the liver; and (3) the intestinal juice, secreted by an enormous number of small glands in the walls of the small intestine. The pancreatic juice and the bile enter together at a point three or four inches from the beginning of the small intestine. The intestinal juice is added to the food at all points throughout the length of the small intestine.

Action of the pancreatic juice. The pancreas is a gland somewhat similar to the salivary glands, although much larger. It is six to eight inches long, two and a half inches wide, and about an inch thick. It lies just behind the stomach and a little below it. It produces three enzymes: (1) One (amylase) acts on the starch which has not already been digested by the saliva. It changes the starch to sugar. (2) Another (trypsin) carries further the digestion of those proteins which have been partly digested by the gastric juice. It reduces them to amino acids. (3) The third (lipase) acts upon the fats (changing



Some digestive glands. The liver has been raised to show the pancreas and the gall bladder with the bile duct. Note that the stomach, which has been removed, was just in front of the pancreas. What are the functions of the pancreas?

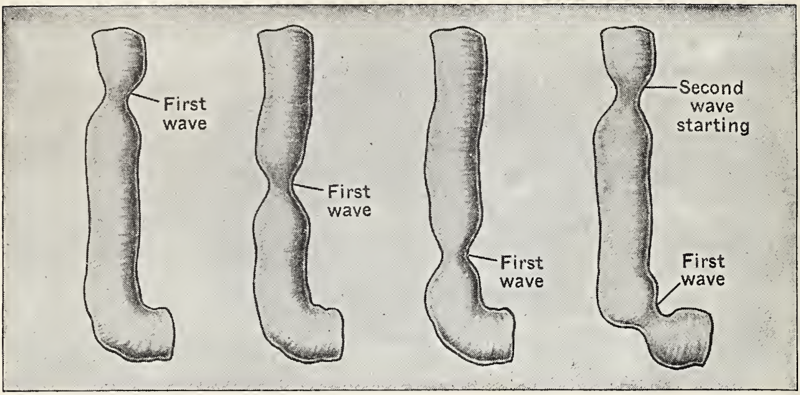
them to fatty acids and glycerol). Before they can be completely digested, however, the fats must be changed to an emulsion (see Experiment 48).

Action of the bile. The bile is secreted in the cells of the liver, which is the largest gland in the body. Bile is constantly passing through the bile duct into the small intestine, but is most abundant several hours after a meal is eaten. It is not a digestive juice, because it contains no enzyme. It does, however, help to change fats into an emulsion. Thus it increases by several times the speed with which one of the pancreatic enzymes (lipase) digests the fats. Bile also helps in the absorption of the products of fat digestion.

Bile is both a necessary secretion and at the same time a waste product, since it contains substances thrown out by the liver. Excess bile is stored in the gall bladder, from which it is poured when additional quantities are needed. Yet the function of the gall bladder is not clearly understood, because men and some of the other higher animals not only have been able to live after the gall bladder has been removed, but have not apparently suffered from its loss.

Action of the intestinal juice. The intestinal juice has four enzymes. One of these (erepsin) completes the digestion of proteins, which is begun by part of the gastric juice (pepsin) and carried on by one of the enzymes (trypsin) in the pancreatic juice. The other three (maltase, invertase, and lactase) complete the digestion of all the carbohydrates, except cellulose. These enzymes change the carbohydrates into sugars which the body is able to absorb.

Action of the small intestine. The digesting food is made to pass through the small intestine as the result chiefly of two separate movements. The first



Using this diagram, can you explain the action of peristalsis in the intestine?

is peristalsis, similar to that of the esophagus and the stomach. The second is a movement which tends to mix the food.

The peristaltic movements serve to force the food through the intestine. They begin at the upper portion of the small intestine and force the food downward, making room for more food to be discharged from the stomach. In the small intestine, however, the peristaltic waves do not follow one another in rapid succession, as they do in the lower part of the stomach. Instead, after the movement has forced the food onward somewhat, the peristalsis stops for a time. Immediately the second movement begins. In this movement rings of muscle at equal distances apart contract. Thus the intestine looks somewhat as a rubber hose would if strings were tied fairly tightly around it at intervals of about two inches. After from about three to ten seconds these rings of muscle relax and another set midway between the rings of the first set contract. The intestine now looks as it did before, except that the bulges and the contractions have exchanged places. After a few seconds these second rings relax, and the first contract again.

In some parts of the small intestine the food may remain for forty-five minutes in one place, being mixed by the motions just described, before another peristaltic movement forces it onward.

By this mixing motion two results are accomplished: (1) The food is mixed more thoroughly with the digestive juices. Hence it is more quickly and completely digested. (2) Fresh portions of the digested food are constantly being pressed against the absorbing surfaces of the intestine. Hence the digested food is more quickly and completely absorbed.

About four and a half hours are required for the first food of a meal to pass entirely through the small intestine. So long a time is necessary in order to give ample opportunity for the food to be completely digested and for absorption to take place. The structure of the intestine is such as to cause food to pass through it slowly. Throughout most of its length it has hundreds of ridges which run most of the way around it. These ridges serve two functions: (1) they delay the food in its progress, and (2) they furnish more surface both for secreting intestinal juice and for absorbing digested food.

***Summary of digestion of energy foods:**

Energy Food	Where Digestion Takes Place	By What Secretions?	By What Enzymes?
Starches	Begins in mouth and continues in esophagus	Saliva	(Ptyalin)[1]
	Is completed in small intestine	Pancreatic juice Intestinal juice	(Amylase) (Maltase, invertase, lactase)
Fats	Begins in stomach	Gastric juice	(Gastric lipase)
	Is completed in small intestine	Pancreatic juice	(Lipase)
Proteins	Begins in stomach	Gastric juice	(Pepsin)
	Is completed in small intestine	Pancreatic juice Intestinal juice	(Trypsin) (Erepsin)

The absorbing surfaces of the small intestine. *The inside surface of the small intestine is not smooth. If it were examined with a microscope, it would look much like a length of velvet arranged in many small parallel folds. Every portion of the surface of the intestine is covered with villi. These are about one fiftieth of an inch in length. Here and there in the sides of the villi are cells which secrete and discharge mucus into the intestine. The chief function of the villi, however, is to absorb the digested food. The digested food enters the villi by osmosis and by other means not yet clearly understood.

The digested carbohydrates and proteins pass into the network of blood vessels in the villi. The fats do not pass directly into the blood. They enter another tube (lacteal) in the interior of each villus. How these digested foods are circulated through the body will be explained in the next chapter.

The large intestine. *The large intestine has three major functions: (1) to serve as a place of temporary storage for food wastes; (2) to absorb water from

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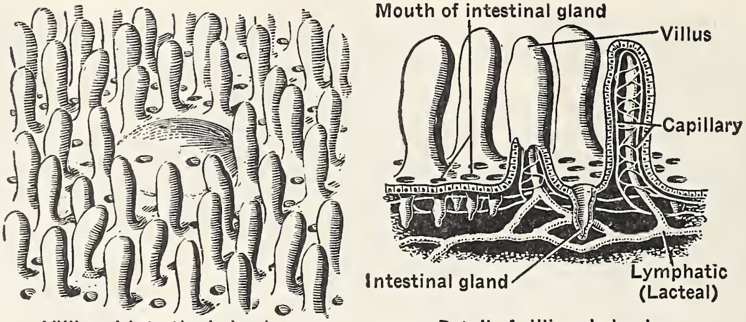
[1] The terms in parentheses are not intended as essential vocabulary (see the Preface, p. v).



Villi and intestinal glands

Detail of villi and glands

The villi of the small intestine. Would absorption be more or less rapid and complete if each villus were a pit like an intestinal gland?

the food wastes; (3) to absorb digested food remaining after its passage through the small intestine.

About thirteen or fourteen hours are required for the food to travel through the large intestine, a distance of about five feet. The materials are forced through it by peristalsis. This occurs for only a few seconds at a time. After it ceases several hours pass before the next peristaltic movements begin.

The materials which finally are eliminated from the body consist of (1) the part of the food which cannot be digested, together with (2) some undigested food, (3) bacteria, and (4) waste products produced within the body.[1]

Bacterial digestion. In the upper and middle parts of the small intestine innumerable bacteria feed upon carbohydrates, producing chiefly carbon dioxide and acid (lactic). This bacterial action is called fermentation. If a person is healthy, this fermentation is not harmful. The bacteria may even do some good in converting cellulose into forms which the body can absorb. If the bacterial action is too great, however, the acids produced irritate the walls of the intestine and cause diarrhea. In the lower end of the small intestine and in the large intestine the bacteria feed upon the waste nitrogen compounds. Sometimes, as a result, they produce poisons which are absorbed by the blood.

Self-test. 1. The two functions of the small intestine are --?-- and --?--.

2. Name the three digestive juices which act upon food in the small intestine and state the organ or organs that produce each.

3. Food is forced through the alimentary canal by *photosynthesis.*

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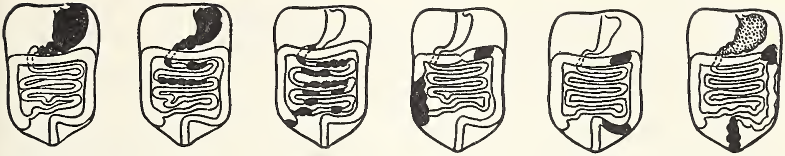
[1] To The Teacher. If it seems desirable to consider the hygiene of digestion at this point, this material will be found in Chapter XXVI.


1 P. M. 3 P. M. 5 P. M. 10 P. M. 7 A. M. 8 A. M.

After Stiles

The time required for food to pass through the intestines. What advantages are derived from the fact that many hours are required in this process?

Self-test on Important Biological Terms

alimentary canal
digestion
enzyme
esophagus
gastric
membrane
mucous membrane
mucus
pancreas
saliva
trachea

Self-test on Biological Principles. **1.** From a study of the preceding sections choose the facts which you would use to illustrate this principle of biology: "Increase in complexity of structure is accompanied by an increase in division of labor."

2. How is division of labor illustrated by digestion in the sponge but not in *Amoeba* or *Paramecium?*

3. How is division of labor illustrated by enzymes?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. **1.** Considering the fact that pancreatic juice acts upon starch, should you expect it to be acid or alkaline? Why?

2. Are the intestinal bacteria parasites in the same sense as the mistletoe (p. 105)?

3. Trace the digestion of a ham sandwich and a glass of milk, naming the organs through which the food passes while being digested and describing the changes which occur.

4. For what reason might it be more healthful to eat warm food rather than cold food? Why should not babies drink ice-cold milk?

5. One stops breathing when one swallows. Can you see an advantage in so doing?

6. In general, the plant-eating chordates have longer intestines than meat-eating animals. What reasons can you give to account for this fact?

Exercises on Scientific Method. **1.** *Making Inferences.* *a.*[1] Two live frogs, each weighing 60 grams, are selected, and two small crayfish, each weighing 20 grams, are also selected. One crayfish is fed to each frog. The frogs are kept at 60° F for three hours and then one is put in the ice chest at 40° F and the other is kept at 80° F in a warm room. What differences will be found in the state of digestion of the crayfish at the end of 48 hours, and why?

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[1] Included by permission of Dr. R. W. Tyler.

b.[1] Protozoa are found in the intestines of certain termites (white ants). These Protozoa can be removed from the intestine without causing any physical injury to the termite. The Protozoa feed on wood pulp which is eaten by the termites. Thirty-six of these termites were selected for an experiment. The Protozoa were removed from the intestines of eighteen of them. These termites ate wood pulp but continued to lose weight, became inactive, and soon died. The other eighteen termites were observed during the same period. They lost no weight, and were active throughout the period of observation. What is the most reasonable and most complete interpretation which you can give of this experiment?

2. *Inventing Experiments.* Devise an experiment which will show that saliva acts on starch but not on protein.

Exercise on Scientific Attitudes. The true story of "the man with a window in his stomach" illustrates how some of the knowledge of digestion grew. Early in the last century (1822) a young Indian, Alexis St. Martin, was brought to a fur-trading post in Michigan with a serious gun-shot wound through his stomach. A young army surgeon, Dr. William Beaumont, treated him. The patient recovered slowly, but the edges of the wound did not grow together. Even after St. Martin was well, there still remained an opening in his stomach, covered only by a movable flap of skin. Dr. Beaumont could look through this opening and observe the process of digestion taking place. He watched the secretion of gastric juice from the walls of the stomach. He tied a piece of meat to a string, put it into the stomach, and discovered that within two hours the meat was completely digested. After he had made many observations, Dr. Beaumont wrote a book describing what he had learned. So complete and accurate were his observations and descriptions of digestion in the stomach that they are still regarded as entirely reliable. Which of the scientific attitudes (p. 624) does this story indicate that Dr. Beaumont possessed?

Special Reports. 1. The figure on page 344 shows the location of the vermiform appendix. What is the nature of the disease appendicitis? How is it treated? (Consult your family physician for information.)

2. What is the nature of commercial rennin (rennet)? What is its relation to the cheese-making industry?

CHAPTER XVII

Transportation and Use of Food in Living Things (Circulation and Assimilation)

Questions This Chapter Answers. 1. What are the functions of a circulatory system? · 2. What are some important facts about circulation in plants? · 3. How do circulatory systems of animals differ? · 4. What are the structures and the functions of the circulatory system in man? · 5. What are the characteristics of the lymphatic system? · 6. What is the effect of alcohol on the circulation? · 7. What are the nature and the functions of the blood? · 8. How does digested food enter the blood? · 9. What is the relation of circulation to health? · 10. How is digested food used in the cells?

HOW IS CIRCULATION CARRIED ON IN PLANTS AND ANIMALS?

Cells somewhat like people. In the earliest pioneer days the problem of securing food was largely an individual or a family matter. Hunters and trappers went off into the wilderness, remaining by themselves sometimes for many months. Families lived miles apart and often saw no members of other families for long periods of time. Every hunter and trapper had to secure his own food, sometimes wholly by his own efforts. Every family had to depend on the activities of its own members for its food supply, and practically every member had some share in these activities. Even in the early settlements where a number of families clustered together for protection, every family was to a large extent independent of the rest and provided its own supply of food with little help from its neighbors.

The problem of securing food is a very different one in our modern great cities. Here few people are engaged in food production. No cities would be possible if every person or every family had to raise its own supplies. The people are gathered together in great numbers to engage in all sorts of useful and necessary work, much of which has nothing whatever to do with food manufacture. Yet everyone must be fed. The city people must therefore secure their food supplies from other people whose chief business is the production of food and who may live long distances away.

With respect to their feeding problems, the individual cells of plants and animals are somewhat like people. The comparison, however, cannot be carried too far. Every one-celled animal or plant, like the solitary hunter or trapper, must secure its own supply of food. The simpler organisms, consisting of relatively few cells, may be roughly compared to the pioneer family. The cells which do not capture food must secure digested food from those cells which do. The cells in the higher plants and animals may be compared to the people in a city. Only a relatively small proportion of the entire number

Armstrong Roberts

In the Grand Canyon, Arizona. If this man is on a week's journey, what kinds of food must he secure for himself and what kinds can he carry with him?

of cells in the organism are engaged in digesting food. But every active cell in every part of the organism must nevertheless secure some of this digested food.

The circulatory[1] system a transportation system. We may think of a complex organism as if it were a huge colony of separate cells, each of which lives its life more or less separately but each of which depends on the circulatory system to bring necessary supplies to it. These supplies include the following:

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[1] *Circulatory* (sûr'kū lă tō rĭ): having to do with the circulation of blood or sap carrying food and other materials to and from all parts of the organism.

1. *Water.* Water is essential for the growth and replacement of protoplasm in every living cell. No animal or plant, therefore, can carry on its normal life activities if it is completely dry. It is true that the lowest organisms, such as bacteria and Protozoa, can become dry and still live for a considerable time. Yet during this period they are in a resting stage. They are carrying on few of their normal activities and these only at a reduced rate. They will resume normal activities only when they are again in water, milk, blood, or some other fluid which is chiefly water.

The simple plants and animals, consisting of relatively few cells, must therefore live either in water or in some other fluid. Also, they must be so constructed that the fluid in which they live bathes, or covers, a considerable number of their cells. In the higher animals every living cell must be bathed in a fluid of some kind, just as *Amoeba* and other one-celled animals are. No complex water animals, such as fish, and no higher land plants and animals ever existed which did not develop some means by which every living cell in their bodies could be bathed in fluid. The circulatory systems of plants and animals perform this necessary function. A circulatory system is therefore an irrigation system as well as a transportation system.

2. *Food.* In the simpler organisms either every cell is able to digest at least part of its needed food, or it is close enough to other cells which digest food to be able to secure from them what food it needs. No circulatory system is necessary, therefore, in simple plants and animals. In the complex organisms, however, most of the cells are too far from the source of digested food to secure it by simple means. Some sort of circulatory system is therefore necessary in order to carry digested foods and other needed materials to every cell.

3. *Minerals.* The mineral substances needed by plants are supplied from the soil. Most of the minerals needed by animals are contained in digested foods. Minerals are carried to all the cells of plants and animals by the circulatory system.

4. *Oxygen.* As was stated earlier, oxidation must constantly take place in every living cell in order that the energy needed by the organism may be released. In all but very simple organisms, oxygen is carried to all parts of the organism by the circulatory system.

5. *Wastes.* The circulatory system must act as a sewer system to carry off the wastes which are excreted by every living cell.

6. *Germ-eating cells.* The circulatory system carries to every part of the higher animals and even of many of the lower forms certain amoeboid cells (the white blood cells). These protect the organism by destroying disease

National Parks Bureau of Canada

Which of the things furnished by the circulatory system does one need after exercising?

germs. These cells leave the blood and enter tissues where they are needed to fight germs. Or they pass out of tissues where they are no longer needed, and travel in the blood stream to other parts which are being attacked.

7. *Hormones.* In the higher animals the circulatory system carries certain substances called hormones, which are manufactured by special glands and which regulate growth and other bodily activities.

8. *Heat energy.* In the higher animals the circulatory system acts as a heat-distributing system, since the body is kept at a fairly constant temperature. For normal adult human beings this temperature varies from about 98.2° F to 99.4° F. Heat must therefore be carried from parts such as the muscles, which produce much heat, to other parts which do not produce enough.

The functions of circulation not separate processes. *It must be kept in mind that the functions of circulation are not separate processes, but that all are being carried on together all the time and in all parts of an organism. Thus cells are taking water, energy (in the forms of food and heat), minerals, oxygen, and hormones from the blood, and at the same time they are putting into it carbon dioxide and other waste products. The blood may be delivering extra heat energy along with needed supplies, or it may be taking away heat along with the wastes.

Self-test. 1. Each cell must digest its own food in *most* of the higher organisms.

2. A *living cell*, to survive, must be bathed in water or some other fluid.

3. Which of the following are functions of the circulatory system of a complex organism: (1) to carry oxygen to every cell; (2) to carry heat energy from the parts where it is produced most rapidly to those where it is produced less rapidly; (3) to act as a sewer system; (4) to keep every cell bathed constantly in fluid; (5) to carry supplies of food energy to every cell; (6) to digest food which has not been digested in the intestines; (7) to cause the heart to beat?

4. What functions of the circulatory system are not named in 3?

WHAT ARE THE IMPORTANT STRUCTURES OF PLANT AND ANIMAL CIRCULATION AND WHAT ARE THEIR FUNCTIONS?

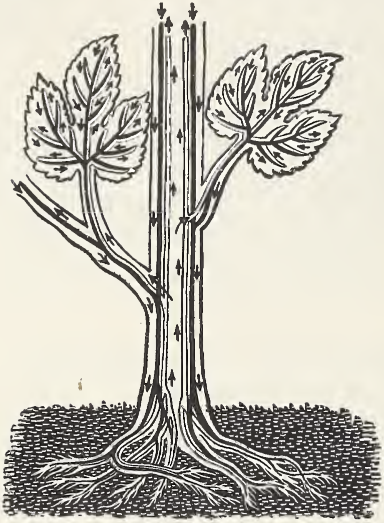
Circulation in the simpler plants. Digested foods and other needed materials pass into bacteria by osmosis. These materials are distributed throughout the protoplasm of the cell chiefly by diffusion, assisted to some extent, perhaps, by the movement of the protoplasm.

Some of the mosses have rudimentary circulatory systems. But no plants simpler than the mosses have special structures to assist in circulation. In nearly all these simpler plants circulation is accomplished by osmosis from cell to cell.

Circulation in higher green plants. *Higher green plants have an extensive circulatory system called the vascular system. This system is needed because the cells in the leaves and stems, where food is made, may be several hundred feet from the cells in the roots, which secure water and minerals. Certain cells, therefore, are concerned wholly with circulation. These cells, arranged end to end, form a continuous system. This runs from the roots through the stem, branching thence to the limbs and to the separate leaves, and continuing through all the leaf veins. Another similar system, parallel with the first, carries liquids and dissolved food materials to all parts of the plant. The structures and the processes of circulation in plants are described in detail in Chapters VI and VII.

Circulation in some of the simpler animals. The simpler animals, like the simpler plants, need no vascular, or circulatory, system. In the Protozoa the process of diffusion and the movements of the animal are together sufficient to circulate the necessary materials through the one-celled body.

With simple water animals, like the sponge, digested food and other necessary materials pass from cell to cell by osmosis, aided by certain amoeboid cells which can move independently among the cells.

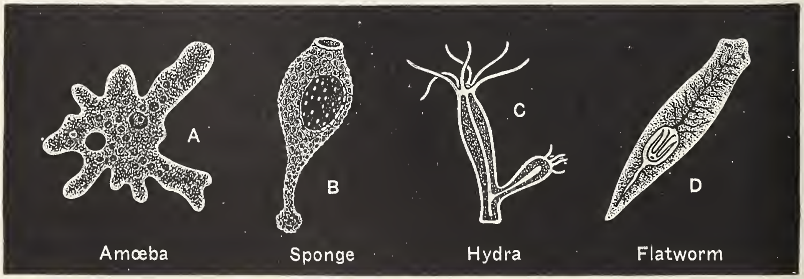


Circulation in a plant. Can you explain the process and describe the structures of circulation in monocots and dicots? (Consult Chapter VII)

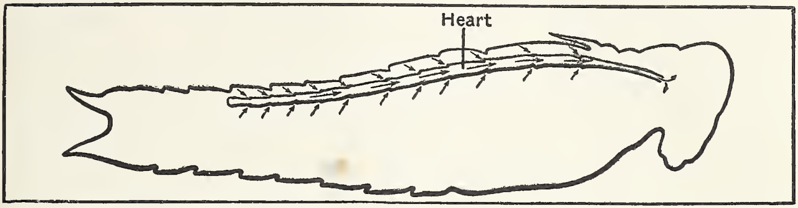
In *Hydra* digested food passes by osmosis from the cells of the inner layer, which capture and digest food, to the cells of the outer layer, which do not. When the inner cells capture and digest more food than the animal immediately needs, this excess food is stored in the outer layer, ready for future use.

In some of the flatworms digested food passes by osmosis through the walls of the intestinal trunks and the smaller branches. These smaller branches lead into every part of the body. All the cells, therefore, are sufficiently close to the supply of digested food to be able to secure nourishment readily by osmosis.

Circulation in higher invertebrates. In Chapter XVI the earthworm was discussed before the grasshopper because the digestive system of the earthworm is more simple than that of the grasshopper. The opposite is true with respect to circulation, although the grasshopper is in general a more complex organism than the earthworm.



In what respects is circulation in each of these animals more complex than that in the animal that precedes it and less complex than that in the animal that follows it?

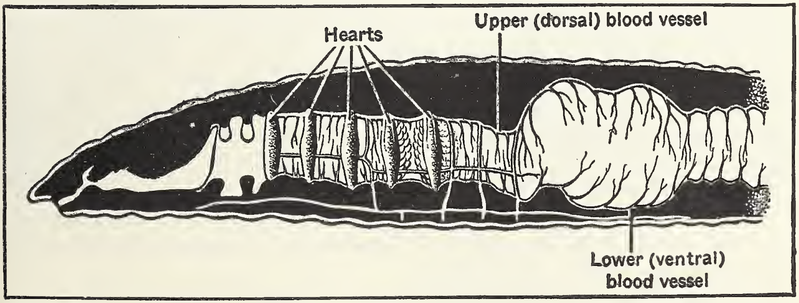


The circulatory system of the grasshopper. In what respects is it more complex than that of any of the animals in the preceding figure?

Unlike the simpler animals just described, the grasshopper and each of the animals which will be discussed in the rest of this chapter have circulatory systems of some sort. In such circulatory systems the blood follows a definite path to the various parts of the body and returns by a different path to its starting point.

The circulatory system of the grasshopper and of insects in general is an example of an open vascular system. Such a system is one in which the blood makes part of its journey through tubes with open ends and the rest through irregular spaces. The grasshopper has a single blood vessel extending down the middle of the back. The rest of the system is merely a body cavity. The colorless blood flows about in this cavity, bathing the various organs. The blood vessel is a crude sort of heart. It pulsates, or beats, forcing the blood out at the front, or anterior, end into the body cavity. Narrow openings (ostia) along the sides of the vessel open inward, permitting the blood to enter from the body cavity.

The circulatory system of the earthworm consists of a system of blood vessels which go to every part of the body. Instead of only one heart, moreover,



The circulatory system of the earthworm. In what respects is the circulatory system of the earthworm more complex than that of the grasshopper and the crayfish?

the earthworm has five pairs of hearts, as will be seen in the figure. These hearts are very simple. Each is scarcely more than an enlarged blood vessel equipped with valves. An upper, or dorsal, main trunk and a lower, or ventral, one run lengthwise in the animal. The hearts connect the upper main trunk, or tube, with the lower trunk. Peristaltic waves, passing from the rear to the front end in the upper main trunk, force blood into the hearts. The hearts pulsate, forcing the blood into the lower trunk. From this it flows into various branches. All the branches, however, lead back finally to the upper main trunk.

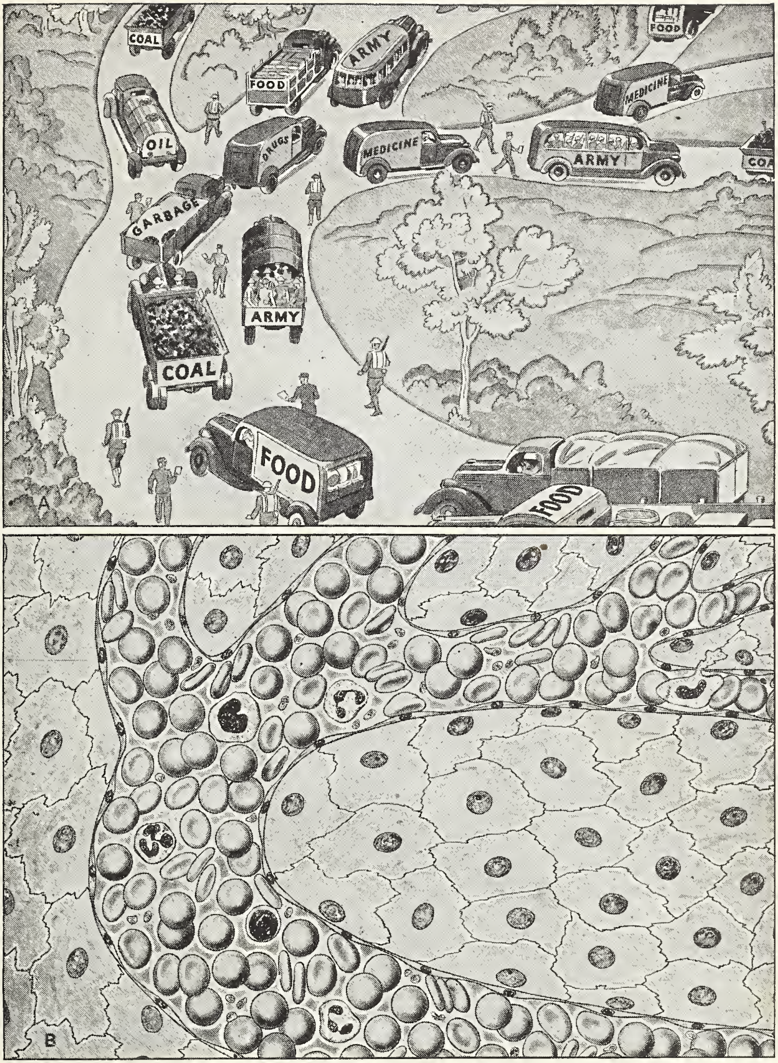
A circulatory system of this type is known as a closed vascular system. In such a system the blood circulates through the body in a series of branching tubes. All higher animals, including man, have closed vascular systems.

Circulation in chordates. The fish has a more complex circulatory system than that of any of the animals previously discussed. It has a two-chambered heart. Also, it has veins, capillaries, and arteries similar to those found in man.

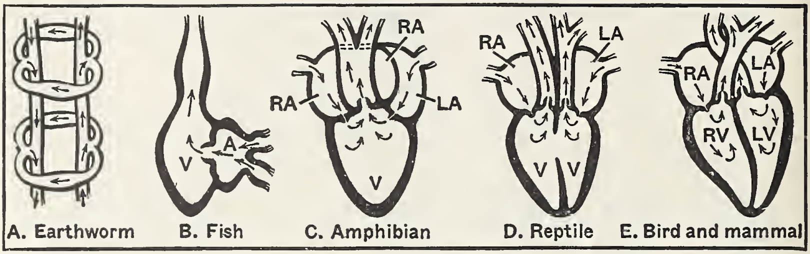
As the blood leaves the heart, it passes to the gills. Here it receives oxygen and gets rid of carbon dioxide. The blood circulates through the body of the fish rather slowly. As a result, there is not a very large supply of oxygen available to oxidize food and thus to release energy in the cells. Such energy as is released is needed chiefly to carry on movement and life processes. Relatively little appears in the form of heat. The temperature of the fish is, then, nearly the same as that of the surrounding water. Fish are therefore said to be cold-blooded animals.

Experiment 50. What is the appearance of the capillaries of a frog, and how does the blood pass through the capillaries? Saturate a piece of absorbent cotton with water containing some ether. Wrap the saturated cotton around a tadpole, or hold the cotton where a frog must breathe the ether fumes. When the animal has become quiet, place the tail of the tadpole or the web of the frog's foot under first the low-power objective and then the high-power objective of a compound microscope. Can you see the many branched capillaries? Can you see the larger blood vessels, that is, the arteries, from which they branch and those which they unite to form the veins? Can you see the blood cells, or corpuscles, passing through the capillaries? Does the blood move more slowly or more rapidly in the capillaries than in the veins and arteries? Can you see any advantage in this change of speed? Are all the corpuscles of the same kind? Summarize the results of your observations in a paragraph or by means of diagrams.

The blood flow may be observed in the fin or tail of a goldfish or a minnow if the fish is treated in the same way as the tadpole in this experiment, or if a few drops of ether are put into the water in which the fish is swimming.



A represents a crowded highway and B a small section of a capillary, or very small blood vessel. A presents several functions of the circulatory system. What functions of the circulatory system B are represented in A? What functions cannot be represented? What structures of the blood are shown in B? (From a drawing by Adrian J. Iorio)



The hearts of various animals. In what respect is each heart more complex than the one preceding it? In these diagrams, A stands for auricle; V, for ventricle; R, for right; and L, for left

The circulation of the frog is more like that of higher animals than is the circulation of the fish. The heart of a frog has three chambers, as the figure on this page shows. These are one ventricle[1] and two auricles.[2]

In the reptile the heart is more highly developed. It has three chambers, two auricles and a ventricle, like that of the frog. But, unlike the frog's heart, it has a wall of tissue which extends down the middle of the ventricle, almost separating it into two chambers.

The bird is the lowest chordate, except the crocodile, which has a four-chamber heart. All the animals above the bird in the scale of life likewise have four-chambered hearts. They also have circulatory systems which are very similar.

Summary of facts about circulation in plants and animals. *In the simplest plants and animals there is no need either for blood or for a special system of blood vessels. The reason is that every cell is sufficiently near the source of digested food and other needed materials so that it can secure these by osmosis. In every complex organism, however, a vascular system is necessary in order that every living cell in every part may be reached. The higher plants have complete vascular systems, but none of the plants has a heart or other organ corresponding to a heart.

*In general, the more complex the structures of animals, the more complex are their circulatory systems. Veins, arteries, and capillaries take the place of spaces or simple tubes. No heart exists in the lowest animals. Higher forms have crude hearts. Still more highly organized animals have more highly organized hearts. Thus there is a simple pulsating vessel in the earthworm and in the grasshopper, a two-chambered heart in the fish, a three-chambered heart in the frog, and a four-chambered heart in the bird, as well as in the rest of the higher chordates, including man.

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[1] *Ventricle* (vĕn'trĭ kl): a chamber of the heart out of which the blood is forced into an artery.

[2] *Auricle* (ô'rĭ kl): a chamber of the heart which receives blood from the veins.

Self-test. **1.** In simple plants liquids are circulated from cell to cell by the process of --?--.

2. In the *simpler animals* no circulatory system is necessary, because no cell is very far from the source of digested food.

3. Describe the three types of circulatory system, which are represented respectively by the higher plants, the grasshopper, and man.

4. Some animals—for example, the *hydra*—have several hearts.

5. In general, the *higher* the animal, the less complex is its circulatory system.

6. The lowest class of chordates in which the four-chambered heart is characteristic is the *mammals.*

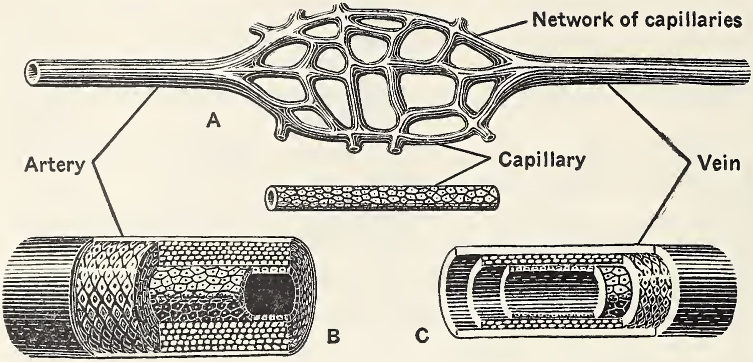
WHAT ARE THE STRUCTURES OF HUMAN CIRCULATION AND WHAT ARE THEIR FUNCTIONS?

The circulatory system in man. The circulatory system in man is composed of the heart, the arteries, the capillaries, the veins, and the lymphatic system. The arteries, capillaries, and veins differ somewhat from one another; yet they are only different parts of the same continuous system of tubes which begins and ends at the heart. Arteries carry blood from the heart, and veins carry it back to the heart. The capillaries join the small arteries to the small veins.

How the blood vessels differ. The wall of an artery consists of three layers: (1) The inside layer is an elastic membrane lined with thin flat cells. (2)The middle layer is a thick one of muscle and elastic fibers. (3) The outer layer consists of bundles of supporting tissue and elastic fibers. As people become older, the walls of the arteries usually become less elastic. This condition is known as "hardening of the arteries."

Although the longer capillaries are only about as long as a dime is thick, they branch again and again to form a microscopic network. Capillaries have only one layer of cells. This layer is the same as that which forms the inside lining of the arteries and veins. This single thin layer permits the passage of materials readily into and out of the capillaries. In a piece of muscle the size of a pin, there are about seven hundred muscle fibers and two hundred capillaries.

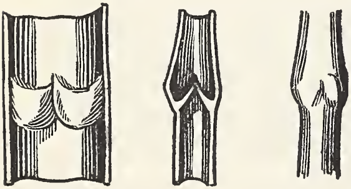
The walls of the veins are composed of the same three layers as the walls of the arteries. The middle layer, however, is much thinner and contains a much smaller proportion of elastic tissue than does the same layer of an artery



Describe the differences in structure of these three blood vessels

wall. Within certain of the veins there are valves. These valves are like pouches. If the blood tends to flow backward, these valves fill and close the passage. The dammed-up blood may then find its way through other tributary veins through which, were it not for the valves, little blood would be likely to flow. Valves are found especially in the vertical veins, where they aid the flow against gravity.

The heart. *The human heart, like that of the other mammals, is a pear-shaped organ located in the middle of the body just behind the breast bone. It is attached to the inner wall of a double-walled bag of tissue (the pericardium). Between the two walls is a small quantity of fluid. This lessens the friction caused by the heart-beats.



Valves in veins. What is the function of these valves?

*The heart is really two pumps, side by side, with the same middle wall serving both. The pumps on both sides act at the same time. Each pump consists of two chambers. The upper one, the auricle, receives the blood from the veins. The lower one, the ventricle, pumps it into the arteries. Heart-beat is caused by the action of the heart muscles. They contract, then relax, and after a brief period of rest repeat the action. Heart-beat is less frequent in adults than in children; in males than in females; in resting animals than in active ones.

The heart is a powerful organ. In forcing the blood through the blood vessels of a hundred-fifty-pound man in twenty-four hours, it does an amount

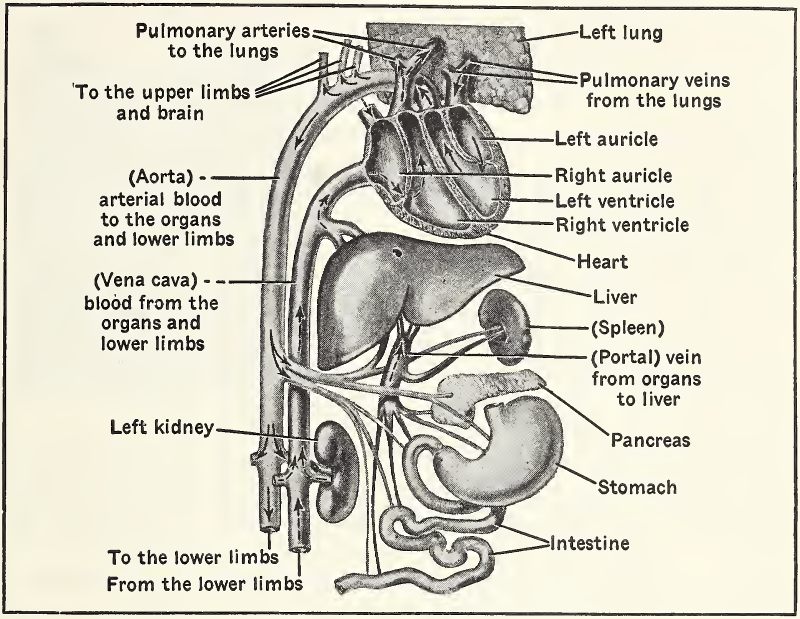

Pulmonary arteries to the lungs
To the upper limbs and brain
(Aorta) - arterial blood to the organs and lower limbs
(Vena cava) - - blood from the organs and lower limbs
Left kidney
To the lower limbs
From the lower limbs
Left lung
Pulmonary veins from the lungs
Left auricle
Right auricle
Left ventricle
Right ventricle
Heart
Liver
(Spleen)
(Portal) vein from organs to liver
Pancreas
Stomach
Intestine

Diagram showing the circulation of blood to various organs. Can you trace the blood to and from these organs?

of work equal to that which would be done in carrying the same man to the top of a hill about a quarter of a mile high.

How the blood circulates. *The work of the heart and the blood vessels is more easily understood if one begins at some point in the system and follows the blood around and back to the same point. It must be kept in mind, however, that the blood is flowing through all parts of the circulatory system at the same time. It must be remembered also that both sides of the heart work at the same time and in exactly the same way.

Let us start with the right side of the heart, at the time of the brief rest period between beats. The muscles of the heart are now relaxed. Blood which has been collected from all over the body is being emptied from the large veins into the right auricle. Since the muscles are relaxed, the valve between the right auricle and the right ventricle is open. Hence part of the blood falls through the valve into the right ventricle. When both the auricle and the ventricle are nearly full, the auricle contracts. Thus it squeezes the blood out of it into the ventricle. The right ventricle then contracts, strongly forcing shut the valve between it and the right auricle. Thus it forces the blood out into the pulmonary artery, leading to the lungs.

As the blood passes through the capillaries of the lungs, there is an exchange of oxygen and carbon dioxide. Thus oxygen passes through the capillary walls from the lungs at the same time that carbon dioxide passes from the blood through the capillary walls into the lungs. The blood now flows from the lung capillaries into the pulmonary veins. These carry it back to the left auricle of the heart.

The heart action just described is now repeated on the left side. During the rest period, both auricle and ventricle fill with blood from the pulmonary veins. The auricle contracts first, forcing the blood into the ventricle. The ventricle then contracts, strongly forcing the blood into the large artery (aorta) leading out into the body. This artery branches into smaller arteries, and these in turn into finer and finer branches, until finally these become the microscopic capillaries in all parts of the body.

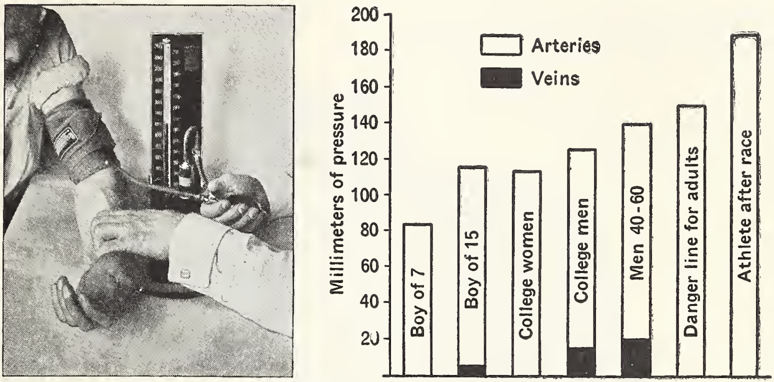
This point marks the end of the journey of the blood away from the heart and the beginning of its return journey. From the capillaries the blood flows into small veins. These unite into larger and larger veins. Finally these lead into the two large veins which pour the blood back into the right auricle of the heart. Valves at the openings of the arteries leaving the heart and at many places in the veins keep the blood flowing in a continuous stream.

Approximately one third of a minute is required for the blood to make a complete circuit from the heart to the most distant parts of the body and back to its starting point again.

Have you ever noticed how the speed of the current varies in a small stream of water as the width of the stream varies? The speed of the blood current is similarly affected by the size of the blood vessels. When the blood leaves the heart in the large artery (aorta), it is moving swiftly. The more the arteries branch, the more paths there are for the blood to take, and therefore the more space the blood must fill. Hence the more slowly it moves. Consequently, by the time it reaches the capillaries, it is moving slowly indeed.

The reverse happens when the blood enters the veins on its way back to the heart. As the many channels or veins come together into larger ones, the blood increases its speed.

The blood vessels are always full. Therefore, when more blood is forced by the heart into the arteries, the elastic walls of the arteries are forced outward by the sudden extra supply of blood. This movement of the walls of the arteries travels along them as a pulse. The elastic nature of the walls, however, steadily resists and reduces the pulse, so that by the time the blood reaches the capillaries its flow is steady.



Measuring blood pressure; graph showing pressures in the arteries and a few corresponding ones in the veins. The graph shows that the pressure in the arteries of a young man, at the instant his heart muscles contract and send forth the blood, is enough to hold up a column of mercury 126.5 millimeters high. Can you interpret the other columns in the graph? How do the pressures in the veins compare with those in the arteries?

Experiment 51. Does the rate of the heart-beat vary under different conditions? Have some member of your class count the number of times your heart beats per minute while you lie down, again while you sit, and once more while you stand. In taking the pulse press the finger, not the thumb, against the artery in the wrist or the temple. Now exercise vigorously for a minute; then have your pulse taken again. State your conclusions in a few sentences.

Blood pressure. The pressure of the blood within the arteries varies with each individual as a result of meals, baths, emotion, violent exercise, whether he is sitting or standing, and other factors. It also varies greatly between each heart-beat and the brief rest period between beats. Normally the pressure for children is less than that for adults. And the normal pressure for women and girls is somewhat less than that for men and boys. Sometimes old people whose arteries have hardened suffer a stroke of apoplexy immediately after a meal because the increased blood pressure has caused a blood vessel to burst.

The lymphatic system. As the blood circulates rapidly through the blood vessels, the liquid portion, or *plasma,* is forced through the walls of the capillaries by a combination of pressure in the arteries and osmotic pressure. It finds its way as tissue fluid into the minute tissue spaces between and around the cells, bathing all of them. From the tissue fluid, individual cells receive food, oxygen, and all other materials which they need. Into the tissue fluid, at the same time, they deliver carbon dioxide and some other waste products.

Thus the tissue fluid rapidly becomes very different in its composition from the plasma inside the blood vessels.

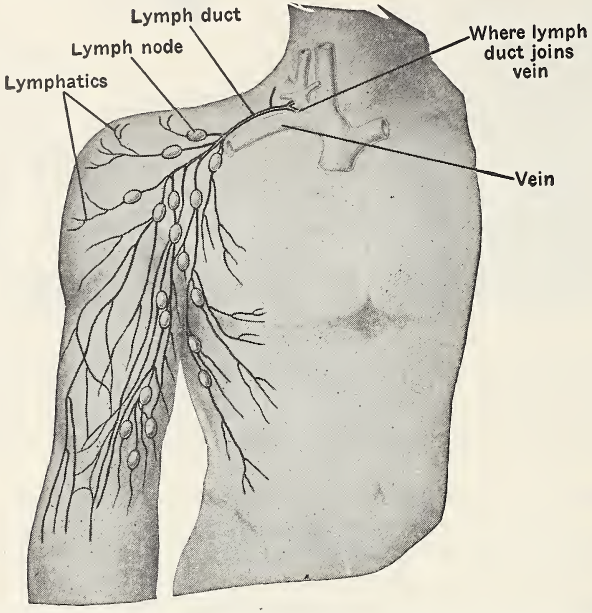


Diagram showing a portion of the lymphatic system. What differences are there between the lymphatic system and the rest of the circulatory system?

Some of the tissue fluid passes back through the walls of the blood vessels, but most of it does not. Consequently there needs to be some way in which the liquid lost from the blood vessels may be given back to them. This need is supplied by a second system, called the lymphatic system.

The lymphatic system is closely associated with the circulatory system, as the figure on this page shows. Plasma enters the tissue spaces faster than tissue fluid passes back into the capillaries. Therefore the tissue fluid is slowly forced from the spaces around the cells into small tubes which lead from the tissue spaces. These tubes are called *lymphatics.* The tissue fluid, after it enters them, is called lymph. The smaller lymphatics lead into larger ones, and these finally into tubes which empty into the veins of the neck. The lymph is forced or squeezed through the lymphatics chiefly by the movements of the muscles. Valves in the lymphatics similar to those in the veins keep the lymph flowing toward the points where it enters the blood stream.

At many points in the lymphatic system the tubes are enlarged to form lymph nodes (sometimes called lymph glands). These are structures composed of spongy masses of fibers. The main function of the lymph nodes is to remove from the lymph harmful bacteria and solid impurities. The bacteria are destroyed by the white corpuscles. These collect in the spaces in the lymph nodes and capture the bacteria from the lymph as it flows through. Solid impurities are strained out of the lymph by the fibers of the nodes. These solid impurities remain stored in the tissues of the nodes.

Alcohol and the circulation. Upon drinking alcohol one's pulse is quickened as if stimulated. This apparent stimulation, however, is believed by certain authorities to be due to the fact that alcohol has interfered with the nerves which control the heart and circulation. The result is a depressing, that is, a narcotic, effect—the opposite of stimulation. Even when small amounts are taken, the heart beats faster and the blood vessels in the skin are dilated more than normally. Because of the increased blood supply in the skin, one feels warm. But the loss of heat from the blood in the dilated blood vessels is rapid and great. While it is true that alcohol is to some extent oxidized in the body to produce heat, nevertheless the gain from this oxidation is less than the loss of heat from the skin. The result, therefore, is that drinking alcohol to keep warm soon leaves the person in greater danger from cold than before.

Health and circulation. Good circulation is necessary to good health. The same general habits which help to keep one healthy help to ensure a healthy circulation. Exercise is especially important, since a primary function of exercise is forcing lymph through the lymphatic system. Fresh air, sunshine, recreation, plenty of good food, regular habits of elimination, and sufficient sleep and rest also have their values. There are, however, diseases of the heart and dangerous conditions of the blood or of the blood vessels which may exist for a long time before becoming sufficiently serious to attract attention. By the time they are detected, they sometimes have become so well established that little help can be given the sufferer. It is a wise policy, therefore, for everybody to have a complete physical examination by a physician once a year.

Self-test. 1. The arteries, capillaries, and veins form one *continuous* system of tubes connecting with the *heart.*

2. The walls of the *capillaries* need to be stronger than those of the veins and the *arteries.*

3. The *blood* bathes our individual cells.

4. The lymph, collected from all parts of the body, is carried by the *circulatory* system and is emptied into veins in the *chest.*

5. Lymphatic glands function in purifying the *blood* of bacteria and solid particles.

6. Name the blood vessels through which the blood passes in flowing from a capillary in your middle finger through the circulatory system and back to the same capillary. Name the various parts of the circulatory system in the order in which the blood would reach them.

7. It is *harmful* to drink alcohol as a protection against cold.

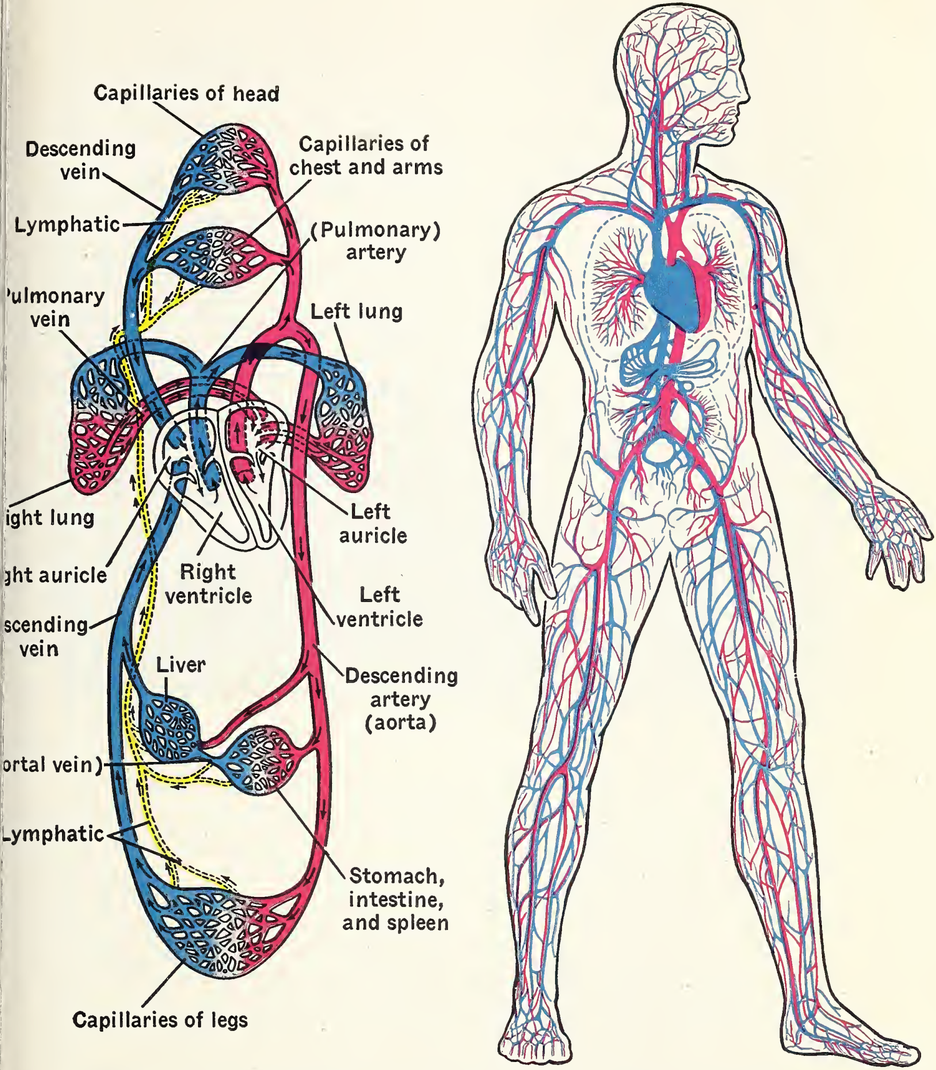
WHAT IS THE NATURE OF HUMAN BLOOD AND HOW DOES IT PERFORM ITS FUNCTIONS?

The blood. There are about six quarts of blood in a man of ordinary size. This blood is distributed in such a way that about one fourth is always in the heart, lungs, arteries, and veins, one fourth in the liver, one fourth in the muscles, and one fourth in all the other organs. You can gain some valuable information concerning the nature of the blood by a simple experiment.

Experiment 52. What is the nature of human blood? Carefully moisten a bit of absorbent cotton in alcohol; then rub the alcohol over the end of a finger in order to kill all germs upon the skin. Sterilize a small needle by dipping it in alcohol or by holding it for an instant in a flame. Squeeze the blood toward the end of the finger. Then stick the needle into the finger and extract a small drop of blood. Place this on a microscope slide and put over it a cover glass. Observe it through first the low-power and then the high-power objective of the microscope. What is the color of the blood as seen through the microscope? Are all parts colored? Do you observe any solid bodies in the liquid? Are these all alike? In order to answer this last question you may need to examine several samples of blood. Summarize your observations in a paragraph accompanied by such sketches as are necessary in order to make clear your findings.

The plasma. The blood consists of about one third corpuscles and two thirds plasma. The corpuscles are special kinds of cells. The plasma is a clear, slightly yellow transparent fluid. It is about 90 per cent water. The remaining 10 per cent is composed chiefly of compounds in solution. These dissolved compounds consist of (1) a number of special blood proteins; (2) the nutrient substances, in the form of sugar, amino acids, and fats which have passed into the blood stream from the villi of the small intestine; (3) various mineral salts which likewise have passed into the blood from the villi; (4) oxygen and carbon dioxide; (5) waste products other than carbon dioxide; (6) hormones from various glands; (7) certain substances which help the body to resist disease.

The blood cells. **The red corpuscles.* Blood corpuscles are of three kinds:



Diagrams of the circulatory system in man. Can you trace the circulation from any point in a blood vessel and back to the same point?

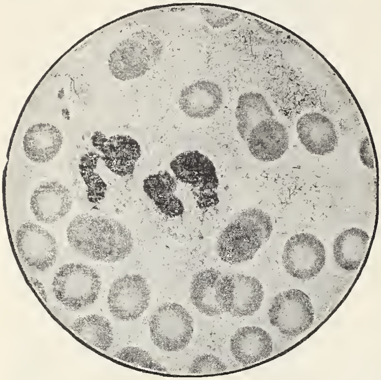
Armstrong Roberts

Why does your heart need to beat faster when you are exercising than when you are not?

red corpuscles, white corpuscles, and blood plates. The red corpuscles of man, except when they are first formed, have no nuclei. However, in some of the lower organisms—for example, the frog—these corpuscles have nuclei. Red corpuscles are constantly being formed in the red marrow of certain bones. The red corpuscle is not really red but is straw color. It gets its color from an iron compound called hemoglobin.

Hemoglobin is the blood substance that carries oxygen. Oxygen combined with the hemoglobin gives the blood a deep-red color. Carbon dioxide combined with substances in the blood gives it a darker, slightly brown tint. When the red corpuscles become worn out, they are broken up, chiefly, it is believed, in the spleen and the liver. The iron compound is retained in the body, but the remainder of the corpuscle is excreted as part of the bile.

Anemia is a diseased condition which may result from one or more of several causes, such as these: (1) the body may not have enough red corpuscles; (2) the red corpuscles may not have in them enough hemoglobin to carry a sufficient supply of oxygen to the cells of the body; or (3) too many red corpuscles may be combined with some substance such as carbon monoxide. In this last case there are not enough uncombined corpuscles left to carry sufficient oxygen to the cells.



Cells of human blood photographed through a microscope. Are there any types of cells in the figure on page 363 that are not shown here?

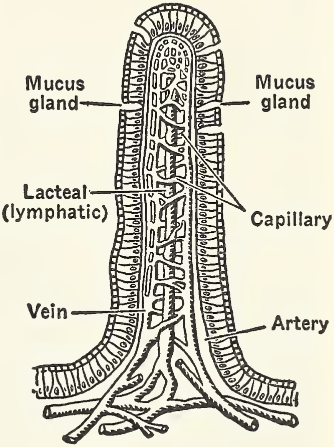
The anemia patient is likely to be pale and to become tired easily. In all cases where this disease is suspected, a physician should be consulted at once. Tobacco-smoking increases the amount of carbon monoxide in the blood and hence may to some extent contribute to the condition of anemia.

The white corpuscles. *The white corpuscles are about one third larger than the red corpuscles. They are, however, far less numerous. They are typical cells, with nuclei. Moreover, each is amoeboid, that is, able to move about independently, like an amoeba, through the walls of the capillaries and among the tissues, as is shown in the figure on page 363. There are three kinds of white corpuscles, which surround and digest bacteria and parts of injured tissue. These corpuscles also produce compounds which make the growth and reproduction of cells possible. Pus is composed of dead and living white corpuscles which have gathered at an infected point to attack invading bacteria.

Where all the white corpuscles are formed is not clearly understood. Some, however, are formed in the red marrow of the bones; others, in the liver and the spleen of the child before it is born; and still others, in the lymph nodes.

The blood plates. The third type of blood cells, the blood plates, cannot be seen in an ordinary sample of blood, (1) because they are very small and (2) because they break up soon after the blood is taken from the body. They are smaller than red corpuscles, and are amoeboid, like the white corpuscles. Their functions are not clearly known, but it is believed that they aid in the clotting of blood.

Blood clotting. We are all familiar with the fact that cuts and scratches usually stop bleeding after a few minutes. A certain protein (fibrinogen) in the plasma causes this clot. It forms long fibers which entangle the corpuscles. The clear yellow liquid which is left after blood has clotted is *serum.* The use of blood serums in the treatment of several diseases will be discussed in Chapter XXV.



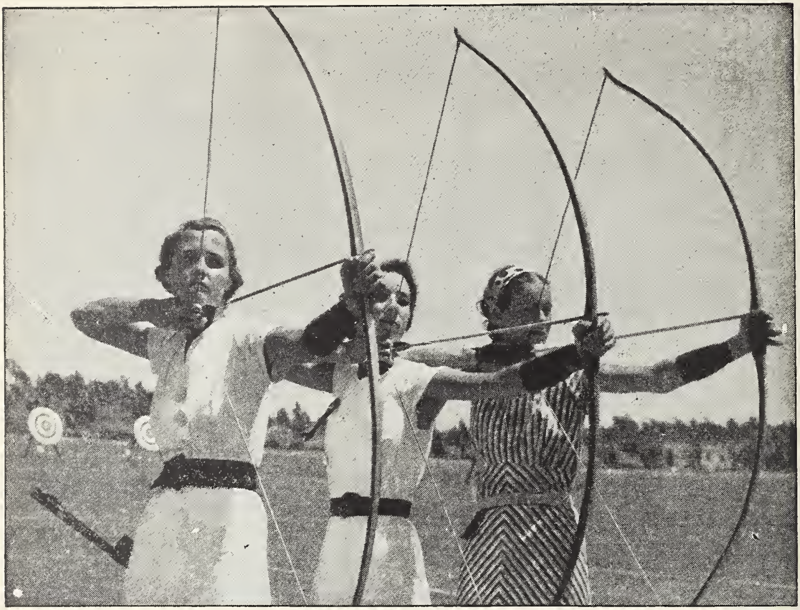
Diagrams of a villus. Can you explain the functions of the various structures shown here?

Sometimes in cases of great loss of blood from bleeding or in some cases of anemia and a few other diseases, lives are saved by performing blood transfusions. In such operations blood from an artery of a normal person is transferred to the veins of the patient. Four types of blood are recognized. The transfusion can be successful only when the blood that is transferred corresponds closely in type to that of the patient.

How the food substances enter the blood. In the preceding chapter the absorption of the products of digestion by the small intestine was described. In the interior of every villus are lymph spaces surrounding a very complex network of blood capillaries. In the middle of this network is a lymphatic. The water, the minerals, and the nutrients pass into the tissue spaces around the capillaries and the lymphatic. These nutrients are (1) carbohydrates in the form of simple sugars, (2) digested proteins probably in the form of amino acids, and (3) digested fats probably in the form of fatty acids and glycerol.

The minerals, the sugars, and the amino acids enter the blood capillaries. From the capillaries they pass into the portal vein (see colored figure facing page 372). Unlike every other vein in the body, the portal vein ends not in a larger vein but in a network of capillaries. These capillaries form a complex network among the tissues of the liver. Therefore all the food in the blood passes through the liver before it is carried to other parts of the body. From 12 to 20 per cent of the sugar in the blood is stored as glycogen in the liver. This is ready for immediate use by the body when the carbohydrate diet is insufficient or when there is need for unusual or violent activity.

The fats do not enter the blood stream directly. They pass into the lymphatics instead and are finally poured into the blood stream at the point where the lymphatic system joins the circulatory system in the neck.



Keystone

Why does oxidation of food take place more rapidly when one is exercising?

Assimilation and oxidation.[1] *Nobody yet knows exactly how the cells use the materials brought to them by circulation. The oxidation of food energy into heat energy, mechanical energy (or the energy of movement), and perhaps into other forms of energy is constantly taking place. The protoplasm of the cell is constantly undergoing chemical changes. As a result, protoplasm is constantly being organized out of materials supplied from the blood stream. The process by which various materials brought to the cells by circulation are built into and made a part of protoplasm is known as *assimilation*. Assimilation may also be defined as the process by which living protoplasm combines organic and inorganic matter into the new compounds which compose protoplasm.

Summary of processes having to do with the use of food. *The stages in the use of food energy by living things are (1) securing the food; (2) taking the food into the body (ingestion); (3) changing the food into liquids of such kinds that they can be taken into the blood (digestion); (4) taking the digested foods into the blood (absorption); (5) transporting the absorbed materials to every living cell in the body (circulation); (6) building new protoplasm (assimilation); and (7) using food materials to supply energy (oxidation).

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[1] To the Teacher. Some authorities include under respiration the release of energy by oxidation. The more general practice among human physiologists, however, seems to be to restrict the use of the term *respiration* chiefly to the exchange of oxygen and carbon dioxide, as discussed in the next chapter.

Two more processes which are related to the use of food remain to be considered: (8) the process by which oxygen enters the cells and carbon dioxide and water leave them (respiration) and (9) the process of waste removal (excretion).

Self-test. **1.** Most of the blood consists of a *red* fluid called *lymph.*

2. Match each expression under *B* with one and only one of those under *A.*

A	*B*
a. Lymph gland	1. Carries oxygen and carbon dioxide
b. Anemia	2. A disease which may be caused by carbon monoxide
c. White corpuscle	3. Destroys bacteria
d. Liver	4. Probably aids in blood clotting
e. Red corpuscle	5. The liquid that remains after blood has clotted
f. Artery	6. First receives the digested food
g. Lymph spaces inside the villi	7. Where reserve sugar (glycogen) is stored
h. Blood plate	
i. Serum	
j. Portal vein	

3. Exercise has value in forcing *plasma* through the lymphatic system.

4. The process by which protoplasm is built and repaired is called __?__.

5. Name the nine processes concerned with the use of food.

Self-test on Important Biological Terms

artery
assimilation
auricle
blood vessel
circulation
circulatory system
corpuscle
heart
hemoglobin
lymph
lymph node
lymphatic
lymphatic system
plasma
vein
ventricle

Self-test on Biological Principles. **1.** Explain the meaning of this principle: "Protoplasm may be nourished only by food substances which have been reduced to liquid form by enzymes."

2. How many illustrations can you cite from this chapter to prove this biological principle: "Circulation is carried on in all living organisms"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Florists often have green carnations for sale on Saint Patrick's Day. These are really white carnations which have been dyed green. Can you explain how this dyeing might be done?

2. Can you give a reason to account for the fact that the circulatory system of the crayfish is more like that of the grasshopper than it is like that of the earthworm?

3. Which of the types of circulatory system (pp. 361 and 362) does the lymphatic system most closely resemble?

4. Does the blood nourish any cells directly? If so, which?

5. Why does the heart do less work when one is lying down than when one is sitting or standing?

6. What advantage is derived from the fact that the blood moves very slowly through the capillaries?

7. Why does the muscular wall of the left ventricle need to be stronger than that of the right ventricle? Why do the walls of the ventricles need to be thicker and stronger than those of the auricles?

8. How many points of contrast between the circulatory system and the lymphatic system can you state?

9. In what respects are the pulse and peristalsis alike, and in what respects are they different?

10. What are some of the inorganic and some of the organic substances which are assimilated into protoplasm?

11. Explain how the valves in the veins keep the blood flowing in one direction.

12. How do parasitic flatworms secure digested food?

13. How does blood in the pulmonary veins differ from that in other veins of the body?

14. Why must the heart beat more rapidly when one exercises?

15. In the figure on page 363 can you find the white corpuscle escaping from the blood stream?

Class Project 21. To find out whether mental conditions such as excitement, worry, fear, and the like affect the rate of pulse beat. Practice until you can take your own pulse accurately. At various times take your pulse—for example, just before you take a test or examination, just before a party or a school game, and so on. Try to find out whether excitement, fear, worry, happiness, and the like have any effect upon your pulse. Combine the results of a week's observations by the entire class and see whether the results indicate definite conclusions.

Exercise on Scientific Method (Evaluating Procedures). What was the advantage of making this a class project rather than an individual one? Could you be sure that all the class members who collected facts or data had the same idea concerning what was a state of fear, excitement, worry, and the like?

Exercise on Scientific Attitudes. In the fourth century B.C. Aristotle, a famous Greek philosopher, taught that the blood of man and the other higher animals was made in the liver from food, and that the blood was then sent to the heart and by it over the body through the veins. Until the time of Galen, in the second century A.D., it was believed that the arteries were merely "air pipes." Galen discovered that the arteries carry blood, but he thought they also carried "vital air," or "spirit." From that time until the time of Harvey, the English physician (1578–1657), only two great discoveries concerning the blood circulatory system had been made. These were the presence of valves in the veins and some facts about the circulation of blood between the heart and the lungs.

By careful work with many kinds of animals over a period of many years, Harvey established the facts of the circulation of the blood and of the functions of the heart and the blood vessels. Harvey's discoveries are all the more remarkable because he had no microscope but only a simple lens.

Malpighi, an Italian physiologist, in 1661 observed the flow of blood between veins and arteries through capillaries. He thus proved that veins and arteries are parts of the same system, as Harvey had stated earlier that they must be. Leeuwenhoek a few years later confirmed Malpighi's discovery by observations through his microscope of the circulation through the capillaries of a bat's wing and of a tadpole's and a fish's tail.

Which of the scientific attitudes (listed on page 624) are illustrated by these facts concerning the history of the study of the circulation of blood?

Special Reports. **1.** Consult a physician to find out what are some dangerous conditions which high blood pressure may indicate.

2. What is a "bleeder" (the medical term for one type is hemophiliac and the disease is called hemophilia)? Consult an encyclopedia or textbooks of European history for the story of hemophilia in the family of the last Czar of Russia, especially in the Czarevitch, the young heir to the Russian throne. Also, secure materials for a similar report on hemophilia in the last royal family of Spain and of the death, in 1939, from hemophilia of a member of that family.

3. During the Second World War soldiers carried tablets containing certain "sulfa drugs" to take in case they were wounded, and also a powder made of a "sulfa drug" to put on wounds. In what ways and to what extent are these drugs effective?

4. During the Second World War the American Red Cross established "blood banks" to provide plasma for blood transfusions for wounded men in our armed forces. Find out from the local branch of the Red Cross as much as you can about these blood banks.

5. Why are men with high blood pressure excluded from the armed forces?

CHAPTER XVIII

Securing Oxygen and Eliminating Carbon Dioxide (Respiration)

Questions This Chapter Answers. 1. Why is respiration necessary? · 2. How is respiration in plants like photosynthesis, and how is it different? · 3. What are the important characteristics of respiration in typical animals? · 4. Why is the respiratory system of higher animals enclosed? · 5. What are the structures and the functions of the human respiratory system? · 6. How are these structures used in breathing?

HOW IS RESPIRATION CARRIED ON IN PLANTS?

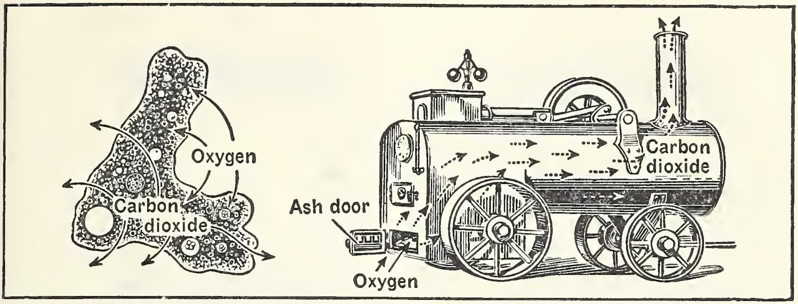
Why respiration is necessary. If amoebas are placed in water which contains no oxygen in solution, the animals soon contract into spheres and form thin-walled cysts. They remain perfectly quiet. While they are cysts, they are able to continue life with the least possible use of energy. If no oxygen is admitted to the water, the amoebas will finally die. The same results follow if amoebas are placed in water which is strongly charged with carbon dioxide. Let us see why these facts are true.

We know that every living thing must secure energy in the form of food. This energy must be transformed into heat energy, mechanical energy, and other forms which the organism needs. To supply these forms of energy, food must be burned, or oxidized, in every living cell. The organism must therefore secure a constant supply of oxygen in order that this oxidation of food energy may take place, just as oxygen must be constantly supplied to a fire in order to keep it burning. The amoebas described in the preceding paragraph died because they could not secure oxygen.

Whenever oxidation takes place, carbon dioxide is always formed. Carbon dioxide is therefore being formed constantly in every living cell. Unless this carbon dioxide is removed, the life processes of the cell stop, just as a fire is extinguished if the carbon dioxide is not allowed to escape.

*Respiration is therefore a necessary process in all living things for two reasons: (1) it supplies oxygen to every cell, thus constantly making possible the oxidation of food and the changing of food to other forms of energy, and (2) it provides for the excretion of carbon dioxide from every living cell.

The nature of respiration. *The process of respiration is chiefly concerned (1) with the use of oxygen by the living protoplasm in the cell and (2) with the passage of oxygen into the cell and of carbon dioxide and water out of the cell. In the higher animals this transfer takes place directly between the cells and the blood (internal respiration) and between the blood and the lungs or the gills (external respiration). In the higher animals, therefore, respiration is made possible by breathing. But none of the plants and none of the lower



In what respects is the amoeba like the engine?

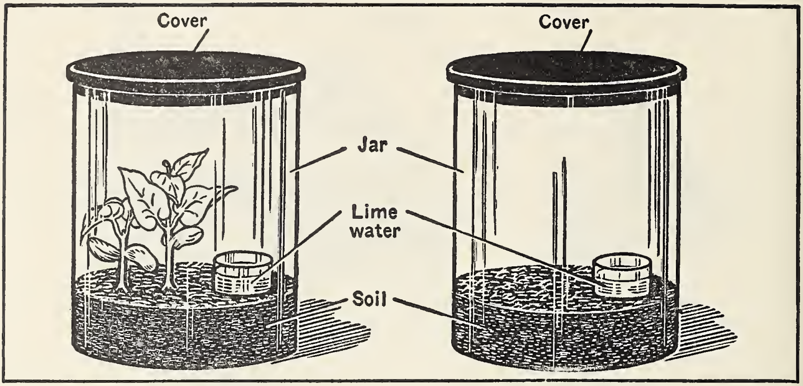
animals breathe. Respiration, however, goes on in every living cell, whether plant or animal. Though the functions of respiration are the same in all living things, the means by which organisms carry on respiration vary considerably, as will be seen from a study of typical plants and animals.

Respiration in plants. In the simplest plants respiration is usually carried on by means of osmosis. Some of the bacteria are able to use the free oxygen which is dissolved in the water, blood, milk, or whatever other fluid their habitat may be. Others (the anaerobic bacteria) cannot use free oxygen; in fact, free oxygen kills them. These must obtain their necessary oxygen from compounds which they secure along with their food or as a part of it. All bacteria get rid of carbon dioxide through their walls by osmosis.

No plants simpler than the mosses are known to have any definite structures which aid respiration. Some but not all of the mosses have crude stomata through which gases enter and leave the plant.

Experiment 53. 1. Does a green plant, such as a bean plant, give off carbon dioxide as a product of respiration? Put into each of two large wide-mouthed jars, such as fruit jars or battery jars, a two-inch layer of rich, damp, sandy soil. In the soil of one jar plant two or three bean seeds which have soaked overnight. Keep the jars in a warm sunny place for several days until the bean plants have developed their second leaves. Now put into each jar a small dish of limewater (see figure, p. 382). Cover each jar to exclude air. Place both jars side by side in a window. From time to time observe the limewater in both jars. Answer with a complete statement the question asked at the beginning of this experiment.

2. Will seeds grow without a supply of oxygen? Secure two small fruit jars or bottles with stoppers. Into each put some moist sawdust or wet paper. Put six soaked bean seeds or other seeds into each jar. Close one jar tightly so that no air can enter. Leave the other jar open and keep the seeds moist. Examine daily for a week. In



Exercise on Scientific Method (Evaluating Procedures and Inventing Check Experiments): Does this experiment help to prove whether or not respiration takes place in *all* green plants? Describe one or more other experiments which would help to answer the question at the beginning of Experiment 53

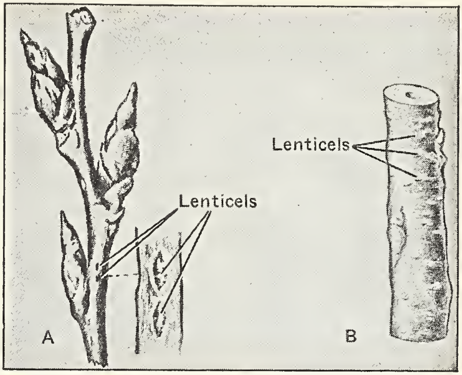
which jar do the seeds grow better? Answer with a complete statement the question asked at the beginning of this experiment?

These experiments provide considerable practice in the use of scientific method. In the first part what was the control? What conditions or factors were identical in both jars? What condition was different? This was the experimental factor. In part 2 did any of the seeds in the sealed jar grow? How do you explain this? (Remember that there was air in the jar when you sealed it.) Can you plan a check experiment similar to the last one, except that all the oxygen is removed from the sealed jar?

In the higher green plants there are stomata in the leaves and young stems, and lenticels in the stems and twigs. The stomata and lenticels together provide for respiration. The passage of gases into and out of the stomata of the leaves has already been discussed in connection with photosynthesis (Chapter VI).

The lenticels develop from stomata in this way: The young stems of plants have stomata, fewer in number than those in the leaves but like them. As a tree gets older, the growth of stem tissues tends to close these openings. Just beneath the stomata, however, a tissue of large thin-walled cells is formed with spaces between the cells. As the tissue grows, it breaks through the outer covering (epidermis) of the trunk. Thus a ready means for gases to pass inward and outward is provided. Lenticels may easily be seen on twigs of the plum, the birch, or the cherry.

Respiration and photosynthesis compared. *Respiration in plants is sometimes confused with photosynthesis. The two processes are, however, very different. In respiration the plant gives off some carbon dioxide and water as waste products. In photosynthesis green plants use carbon dioxide from the air and give off quantities of oxygen as a by-product. This latter statement does not mean, however, that green plants do not use oxygen while photosynthesis is going on. Every living cell in green plants, as in every other organism, uses oxygen constantly in changing its food energy into other forms of energy. While photosynthesis is continuing, however, the plant produces more oxygen than is needed by its cells for respiration. Only the excess oxygen is given off.



A, lenticels on a twig; B, lenticels on birch bark. Why are lenticels more necessary on a young stem or twig than on an old one?

Self-test. **1.** The two functions of respiration are --?-- and --?--.

2. Respiration in all animals takes place in the *lungs*.

3. Respiration in the simplest plants is carried on by the process of *transpiration*.

4. *Gases* pass into and out of higher plants through --?-- and --?--.

5. In *some* green plants respiration and photosynthesis may be carried on at the same time.

6. The process of respiration takes place in *most* organisms, but the process of breathing takes place in the *lower* animals.

HOW IS RESPIRATION CARRIED ON BY WATER ANIMALS?

Respiration of invertebrates. The simpler animals cannot take oxygen directly from the air. They can use only oxygen which is dissolved in water, blood, or some other fluid. Therefore. as in the simplest plants, respiration in the Protozoa is effected by osmosis of oxygen from the surrounding liquid and of carbon dioxide into the surrounding liquid. In the sponge and in other simple Metazoa, there are likewise no special structures for breathing. Oxygen and carbon dioxide are exchanged directly by the individual cells.

The starfish has special structures, though simple ones, for respiration. Scattered over the spiny surface are minute pores. Delicate tissue is thrust out through these pores into the water. This tissue provides a considerable surface area through which oxygen passes from the sea water into the body fluid and carbon dioxide passes out at the same time into the water.

Neither the protozoan, A (*Stylonychia*), nor the sponge, B (*Olynthus*), needs gills or special breathing apparatus. Explain

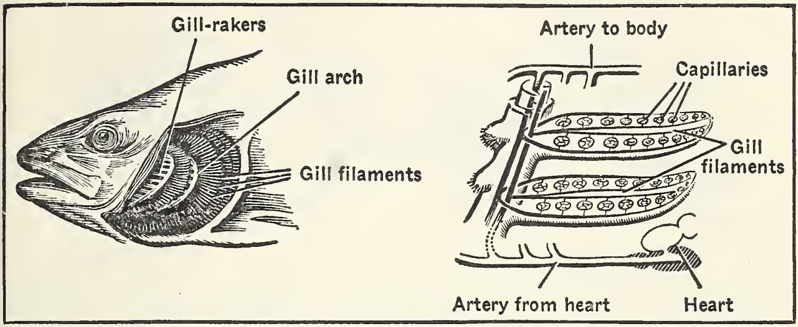
The clam and the oyster have gills. Also, they have special structures which maintain a constant flow of water over the gills, just as man's breathing apparatus brings fresh supplies of air to the surface of the lungs. Gills consist of delicate, thin-walled membranes arranged like the teeth of a comb. An enormous surface area is thus provided. A network of blood capillaries just under the surface of the gills makes possible a ready exchange of carbon dioxide from the blood into the water and of oxygen from the water into the blood.

The crayfish is well provided with gills. These are not inside the body cavity but are between the body wall and gill cover. Each gill, with its stem and many branching filaments, looks like a plume, as is shown in the figure on page 190. In the front end of the gill chamber is an organ (the *bailer*). This moves back and forth, forcing water out through an opening in the front and thus reducing the pressure in the gill chamber. The greater pressure of the water outside forces fresh water into the gill chamber through a rear opening. A continuous circulation of water is thus provided. Blood flowing through the gill stems and the filaments gives off carbon dioxide to the water and takes in oxygen from it.

Respiration in the fish. Along the sides of the head of a fish are two flaps, the gill covers (opercula; singular, operculum). These open and close regularly as the fish breathes. The fish takes in a mouthful of water, then closes its mouth and forces the water back over the gills and out past the gill covers.

Under each gill cover there are four or five gills. A gill is composed of a bony arch to which are attached many short filaments. These filaments have very thin walls, through which carbon dioxide and oxygen pass readily. Moreover, the great number of them increases the surface which can absorb oxygen.

Inside each filament there are numerous capillaries. These bring the blood into close contact with the water. As the blood circulates through the filament,



Location and structure of fish gills. A fish that eats crayfish, mollusks, or other fish has short gill-rakers, but a fish that feeds on minute plants and animals has numerous long gill-rakers. How are these animals helped by these structures? What in this picture corresponds to the pulmonary artery in man?

carbon dioxide is given off. At the same time oxygen is taken into the capillaries and thence into the blood stream. The fish has nostrils, but these serve only as organs of smell.

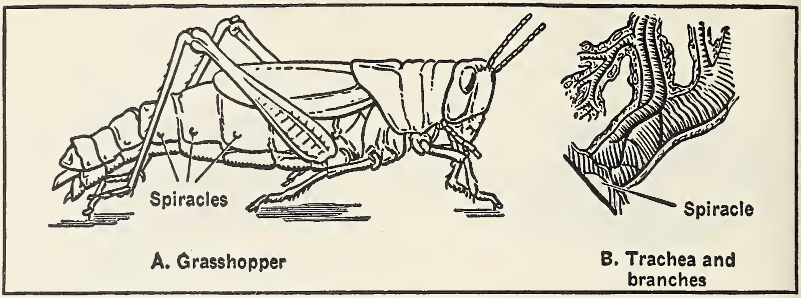
On the inner edge of the gill arch are bony projections (gill-rakers). They serve two purposes: (1) they strain out bits of food that the fish can use, and (2) they catch solid pieces which, if allowed to pass from the mouth to the gills, might injure the delicate gill filaments.

Self-test. Match each word under *B* with one and only one word or expression under *A*.

A	*B*
a. Lenticel	1. Protozoan
b. Gills	2. Starfish
c. Carbon dioxide a life necessity	3. Mollusk
d. Lungs	4. Crayfish
e. Neither lungs nor gills but tissue to absorb oxygen	5. Fish
f. Transpiration	
g. Secures oxygen only by osmosis	
h. Stoma	
i. Oxygen a by-product	

HOW IS RESPIRATION CARRIED ON BY AIR-BREATHING ANIMALS?

Respiration in air-breathing invertebrates. Although the earthworm has a complex circulatory system, nevertheless its manner of respiration is simple. It takes oxygen into its body and gets rid of carbon dioxide through all por-



The breathing pores and air tubes of a grasshopper. **Self-test on Biological Principles:** Compare the means of respiration of the snail with that of the earthworm and the grasshopper. Do the respiratory structures of these animals furnish an example of or an exception to the biological principle "In general, the more complex the organism, the more complex its various structures"? Justify your answer

tions of its moist skin. Just beneath the skin are numerous thin-walled capillaries. Through the walls of these, oxygen and carbon dioxide readily pass. The exchange of gases through the moist skin and moist membranes is probably caused by osmosis. In the earthworm the red coloring matter of the blood is in the plasma rather than in the corpuscles. Oxygen combines with this red material of the blood and is circulated to every cell. Carbon dioxide, mostly in solution in the blood, is carried from all parts of the body to the capillaries under the skin.

If you were to hold a grasshopper's head under water, it would not drown. Moreover, if you were to trace the mouth cavity back into the body, you would search in vain for any structures having to do with respiration because the grasshopper does not breathe either through its mouth or through nostrils. Furthermore, in the grasshopper no use is made of the circulatory system in carrying oxygen to any of the cells or carbon dioxide from them. How, then, is the grasshopper supplied with oxygen, and how does it get rid of carbon dioxide?

Along each side of the abdomen of the grasshopper are eight small holes, and two more along each side of the thorax. These are the breathing pores (spiracles). They are the beginnings of a complex system of air tubes. The tubes (tracheae), leading from the breathing pores, branch again and again, and thus lead to every part of the insect's body. Carbon dioxide passes directly from the cells into the breathing tubes, while oxygen passes from the tubes into the cells.

The grasshopper breathes by expanding the abdomen, reducing the pressure in the air tubes. The air pressure outside then forces air into the tubes.

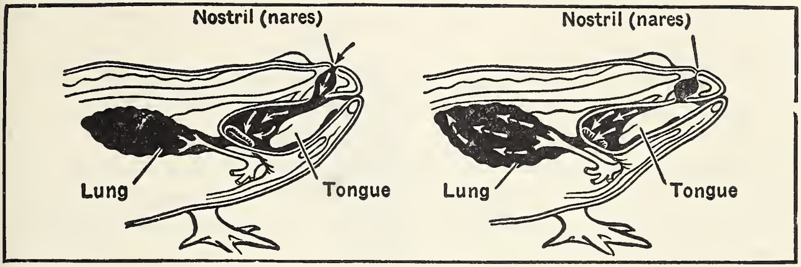


Diagram showing how a frog breathes. Why does a frog keep its mouth closed while breathing, although a fish does not? Can you explain from this diagram what takes place when a frog inhales and exhales?

When the abdomen is contracted, the air in the tubes is compressed, and some of it is therefore forced out of the tubes.

The snail, although simpler in most of its structures than the grasshopper, has a more complex respiratory system. It has a primitive lung. In some forms this primitive lung branches into a number of smaller air tubes (tracheae). The membrane (mantle) lining the lung cavity is supplied with numerous blood vessels. These take up oxygen and get rid of carbon dioxide, as in the higher animals.

Respiration in the frog. *The frog eliminates carbon dioxide and takes in oxygen in two ways: (1) to some extent through its moist skin, both when the animal is in the water and when it is on land, and chiefly (2) through the moist membranes of its lungs.

In the back of the frog's mouth is a slit (glottis). This opens into a short tube (trachea) which branches to the lungs. The lungs are two elastic sacs,[1] the inner surfaces of which are greatly increased by numerous folds in the walls, forming small spaces (alveoli). The thin walls contain a network of blood capillaries.

If you watch the under-side of the frog's mouth, you can see the breathing movements. When the frog breathes, it keeps its mouth closed. When it inhales, or breathes in, it lowers the floor of its mouth, forming a partial vacuum in the mouth cavity and opening the nostrils. The greater air pressure outside forces air through the nostrils into the mouth cavity. The floor of the mouth is then raised, closing the nostrils and compressing the air in the mouth cavity. The compressed air is forced into the lungs.

When the frog exhales, or breathes out, it contracts the muscles in the body wall, compressing the air in the lungs and forcing it into the mouth cavity.

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[1] *Sac* (săk): a bag-like structure.

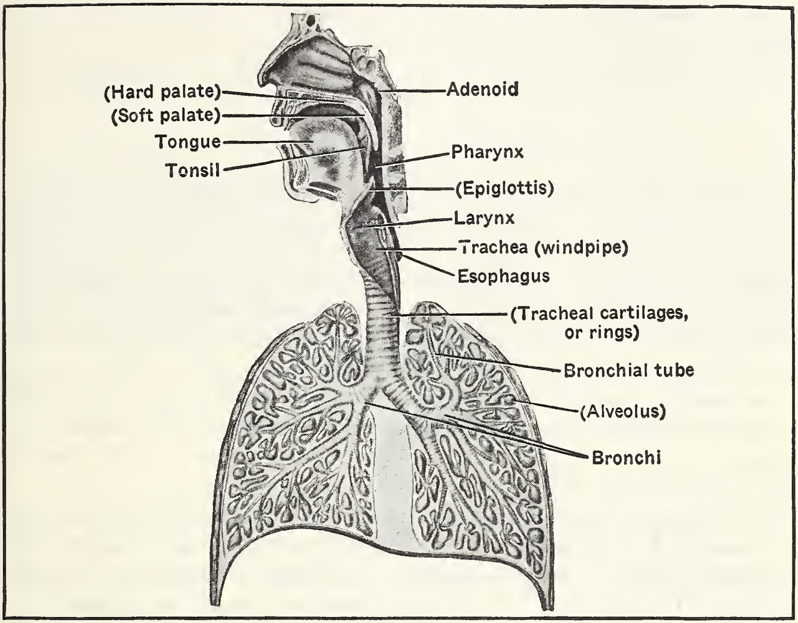
The ability of the frog to "breathe through its skin" enables it to hibernate. As cold weather approaches, the frog goes to the bottom of a pond or stream and burrows into the mud. Here it remains all winter. If dug out, it is apparently dead. This dormant state is due to the fact that all the life processes are slowed almost to the stopping point. While hibernating, the frog can get only such oxygen as can be taken in through the skin. Also, oxidation of fat that has been stored in the frog's body goes on only fast enough to keep the animal barely alive. When warm spring weather comes, the frog again becomes active.

Like the frog, all other cold-blooded animals are able to live when their body temperature is reduced to that of their surroundings, provided the temperature is not low enough to kill the protoplasm in their cells.

The enclosed respiratory systems of higher animals. The frog is able to use its skin as an organ of respiration only if it can keep its skin moist. Therefore it must spend part of its time in the water. If it were away from the water long, it would be unable to replace from its body fluids all the moisture evaporated from its skin. Hence it would die.

Higher animals, living on land, cannot exchange carbon dioxide and oxygen through their skins. The reason is that they are not so constructed as to be able to supply to their skins the great amounts of water which would be evaporated in the process. They are able to survive only because they have their breathing surfaces enclosed within their bodies, where evaporation will not be great. There is little evaporation from the lungs and nasal passages of higher animals for the same reason that there is little evaporation from the contents of a bottle which has a small neck.

Summary. *Respiration in every organism takes place only through moist cell walls. The simplest plants, such as bacteria, and the simpler water animals secure oxygen and get rid of carbon dioxide directly through the cell walls by osmosis. The higher green plants have special structures, stomata and lenticels, through which these gases pass to and from the interior of leaves and stems. In the more complex animals special respiratory structures are necessary in order (1) to provide enough oxygen for the cells farthest from the surface and (2) to remove carbon dioxide as fast as it is returned from them. The starfish, a fairly complex animal, has special tissues over all its body which function in this way. Still more complex animals cannot be served by simple structures scattered in various parts of the body. These have specialized structures of respiration, either gills or lungs, located in one part of the body. The simplest animals have their respiratory structures exposed; the highest animals have their respiratory structures enclosed thus preventing excessive evaporation.



Can you locate on this diagram the conspicuous divisions of the respiratory system? What other structures are labeled? The inner surfaces of the lungs have a total area over one hundred times that of the body

*All the land animals more complex than the frog, namely, the reptiles, the birds, and the mammals, eliminate carbon dioxide and secure oxygen by means of lungs. There are minor differences in the breathing structures of the different higher animals, but there are no differences so great as those that have been described in the preceding paragraphs. The remainder of the chapter will be devoted to the breathing structures of man as a representative of the higher chordates.

Self-test. **1.** The earthworm takes in oxygen and gets rid of carbon dioxide through its *mouth*.

2. In the *insects* air tubes serve the same purposes in making possible the transfer of oxygen to the blood and carbon dioxide from it that are served by __?__ in the higher animals.

3. The simplest animal here discussed which has a lung is a (1) mollusk; (2) arthropod; (3) mammal; (4) protozoan; (5) annelid; (6) angiosperm; (7) coelenterate.

4. The *Amphibia* are able to breathe partly through their skins because they live *always* in the water or in damp places.

5. All vertebrates except the --?-- breathe partly or wholly with lungs.

HOW IS RESPIRATION CARRIED ON BY MAN?

Structure and Functions of the Human Respiratory System. *The respiratory system in man is a continuous tube with an enormous number of branches at the lower end. The conspicuous divisions of this system are the nose, the pharynx, the larynx, the trachea, the bronchi, and the lungs. The latter consist of the bronchial tubes and the innumerable small sacs (alveoli) in which they end. The tube is open throughout except at the larynx, that is, the voice box. This opens through a valve-like slit into the pharynx, or throat cavity.

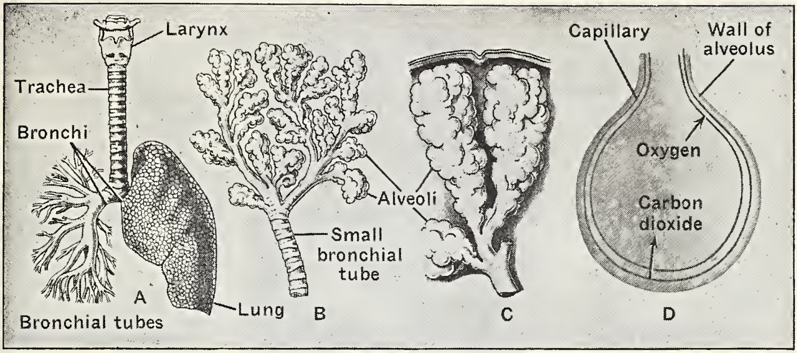
In man the passages of the nose are lined with mucous membrane. The mucous membrane serves to moisten the incoming air. The nostrils are equipped with coarse hairs which together act as a strainer, or filter, freeing the air from dust particles.

The trachea, or windpipe, is a tube about five inches long by about an inch in diameter. It has sections of cartilage in its walls to prevent its closing. The two bronchi and the larger bronchial tubes likewise have these sections of cartilage. The smallest bronchial tubes, however, are not so equipped.

Each cell of the lining of the trachea, the bronchi, and the lungs is equipped with cilia. These are constantly in motion. If a section of the lining is examined through a microscope, it looks like a field of grain when breezes pass over it. Since the cilia all move with more force in the direction of the throat than toward the lungs, the motion tends to carry dust, smoke particles, and other solid particles upward into the throat. It is said that even a coal-mine worker, in whose lungs a great amount of coal dust collects, will, in the course of several months, become free of the dust by this action of the cilia if he leaves the dust-laden air.

The lungs are two spongy, elastic structures lying one on each side of the chest, with the heart between them. Each lung is enclosed in an elastic airtight sac (pleura). The walls of this sac are moistened with fluid which lessens the friction caused by the lung movements.

It is estimated that each lung contains about four hundred million tiny air sacs. Each air sac has many small blood capillaries in its walls. Through the thin walls of the sacs oxygen passes into the blood capillaries and carbon dioxide and water vapor pass from the capillaries into the sacs. It is estimated that the entire absorbing space of the lungs equals an area about fifty feet square.



Lung structures: A, lungs and air passages; B, enlarged drawing of small bronchial tube; C, enlarged drawing of one of the final branches. Why is it useful to have a many-branched lung rather than a solid mass of lung tissue? What does D show?

We may think of the lungs enclosed in their sacs (the pleurae) as being in a box (the thorax). The sides are formed by the backbone, the breastbone, and the ribs, with the attached muscles. The bottom is formed by the diaphragm. This is a dome-shaped sheet of tissue separating the chest cavity from the abdominal cavity.

How we breathe. Inhaling, or taking air into the lungs, is accomplished as the result of these separate movements: (1) The muscles of the diaphragm contract, pulling the diaphragm downward. Thus they force the organs of the abdomen downward and cause the walls of the abdomen to bulge outward. (2) Certain muscles attached to the ribs and breast bone contract, pulling the ribs and the breast bone upward. Each of these movements enlarges the chest cavity and thus reduces the pressure between the lungs and the walls (the pleurae) of the lung cavity. The lungs expand until they almost fill the cavity around them, with the result that the air pressure within them is reduced. The greater air pressure outside the body, therefore, forces air through the nose and trachea into the lungs until the air pressure inside and outside the lungs is the same.

When one is exhaling, air is forced out of the lungs in this way: The diaphragm arches upward. The muscles of the abdominal wall and other muscles produce a pressure inside the abdomen, forcing the diaphragm up farther. The bones of the chest immediately sink downward. The lungs are therefore compressed, with the result that the air pressure in them is increased. Some of the air is therefore forced out of the lungs until the air pressure is again the same inside as out.

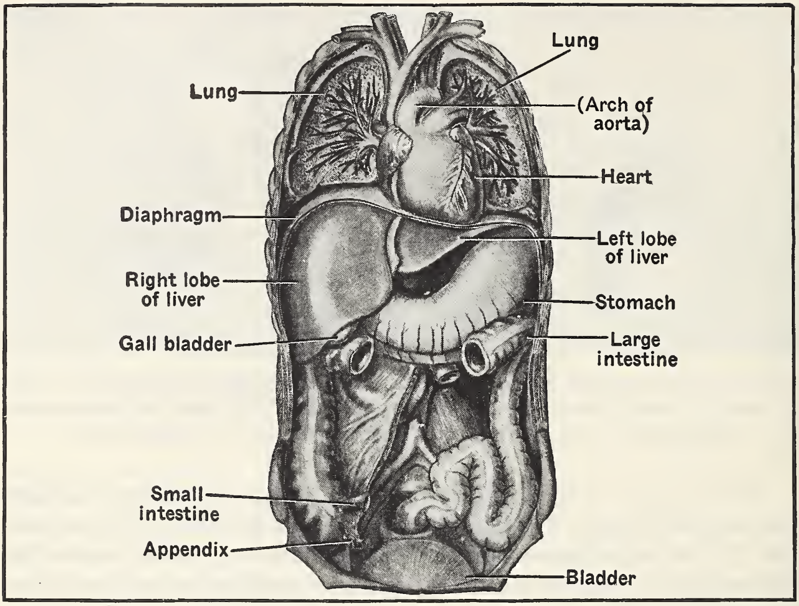


Diagram showing the diaphragm and other respiratory structures. In what respects are the human lungs and a fish's or a crayfish's gills similar?

A grown person normally has on an average about eighteen inspirations[1] per minute. Children have more. Babies less than a year old have more than forty inspirations per minute. The number of inspirations may decrease nearly one third during sleep. The inspirations during sleep, however, are deeper than when one is awake.

Self-test. 1. Trace air from the time it enters the nose until it is breathed out of the nose.

2. The air which enters the respiratory system is made both *dry* and *warm*.

3. Hairs in the nose remove --?-- from the incoming air.

4. The lungs have enormous surface areas in order to provide ample surfaces for absorbing --?-- and getting rid of --?--.

5. When the air pressure outside the lung cavity is greater than that within the lung cavity, air is *pulled* into the lung cavity.

6. Oxygen enters and carbon dioxide leaves the blood stream through the walls of the lungs at *the same* time.

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[1] *Inspiration* (ĭn spĭ rā'shŭn): act of inhaling, or drawing in the breath.

Self-test on Important Biological Terms

diaphragm
esophagus
gill
larynx
lenticel
lung
pharynx
respiration
respiratory system
trachea

Self-test on Biological Principles. What evidence is there in this chapter that complexity of structure is accompanied by an increase in division of labor?

Self-test on Organization of Facts. In what respects is the respiratory apparatus of each animal discussed in this chapter more complex than that of the animal preceding it?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why must all Amphibia live usually in water or in damp places?

2. What advantage is derived from the fact that the smallest bronchial tubes are not equipped with sections of cartilage?

3. After a heavy rain one may find many earthworms on the surface of the ground. If they remained in their burrows, they would drown. Explain.

4. How does the exchange of oxygen and carbon dioxide in an amoeba resemble respiration in man? How does it differ?

5. What changes in one's breathing habits would one expect in going from sea level to a high altitude?

Exercises on Scientific Method. 1. *Making Inferences.* A crayfish in running water rests with its head pointed in the direction in which the stream is flowing. A fish, on the other hand, rests with its head pointed against the current. Can you use your knowledge of the methods of breathing of these two animals to explain the probable reason for this difference?

2. *Inventing Experiments.* Can you plan an experiment which will show whether or not germinating seeds give off carbon dioxide? Be sure to introduce controls.

Special Report. Find out all you can about the respiration of the larvae of certain insects, such as the dragon fly, the May fly, and the mosquito, which in the larval stage are water animals but later live on land. (Consult a textbook of entomology or an advanced textbook of zoology.)

CHAPTER XIX

Getting Rid of Waste Products (Excretion and Elimination)

Questions This Chapter Answers. 1. What is the meaning of excretion? · 2. How is excretion carried on in plants and animals? · 3. What are the organs of excretion in man, and how does each function? · 4. Of what importance is excretion?

WHAT IS THE NATURE OF EXCRETION?

Why excretion is necessary. If an automobile engine or a coal furnace were constructed without some means by which waste products of combustion could escape, it would not function. The transformation of energy in the automobile engine or in the coal furnace can continue only if the waste products are removed about as rapidly as they are produced.

Waste products are constantly being formed as a result of metabolism[1] in every living cell. Like the automobile engine and the furnace, the cell will cease to function, and consequently the organism will soon die, if its waste products cannot be eliminated.

Waste products. *Waste products of living things may be placed in three groups: (1) the solid portions of food which are not digested or which cannot be digested; (2) the excess water which is not used by the body; (3) the waste products which result from metabolism in the cells, namely, carbon dioxide, urea,[2] other organic compounds, and water. The various processes by which an organism eliminates, or gets rid of, the wastes produced by metabolism are called *excretion*.[3] The various organs, together with the tubes connecting them, make up the *excretory system*.

The chapter on digestion discussed the elimination of undigested food materials from intestines. In the simpler animals undigested solid wastes are cast out through the cell walls or through the mouth. In most of the animals which have a digestive system, solid wastes are eliminated from the intestines. Solid wastes of plants are deposited in the leaves, in the stones of certain fruits, and in the pith cells. The shedding of leaves is one means by which plants get rid of these wastes.

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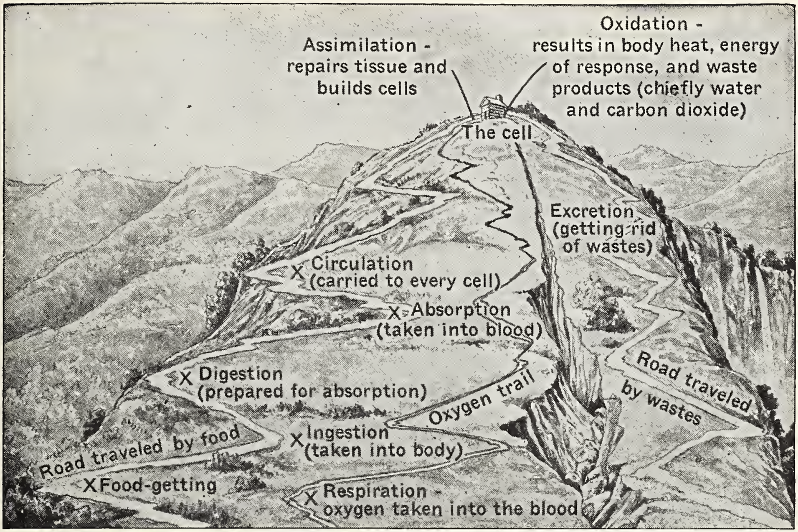
[1] Metabolism is divided by biologists into anabolism and catabolism. *Anabolism* includes all the processes concerned with building protoplasm from simpler substances. *Catabolism* includes all the processes concerned with breaking down protoplasm into simpler substances. Anabolism and catabolism are going on constantly in all parts of every living thing.

[2] *Urea* ((ū rē′ȧ): a waste product of metabolism resulting from the oxidation of nitrogen compounds.

[3] To the Teacher. It is recognized that technically excretion includes the elimination only of the products of metabolism, namely, carbon dioxide, urea, other organic compounds, and water. For the sake of simplicity, however, the term *excretion* is here used to include the elimination of all wastes. This chapter discusses chiefly excretion of wastes from metabolism, since the elimination of other wastes is discussed in preceding chapters.


Assimilation - repairs tissue and builds cells
Oxidation - results in body heat, energy of response, and waste products (chiefly water and carbon dioxide)
The cell
Excretion (getting rid of wastes)
X Circulation (carried to every cell)
X Absorption (taken into blood)
X Digestion (prepared for absorption)
Oxygen trail
Road traveled by wastes
Road traveled by food
X Ingestion (taken into body)
X Food-getting
X Respiration - oxygen taken into the blood

The metabolism trail. Can you explain this diagram? What processes occur before metabolism takes place? What processes are included in metabolism?

The chapter on respiration described the elimination of carbon dioxide as taking place at the same time and by means of the same structures as are used in the securing of oxygen. Carbon dioxide passes out through the cell walls in the simplest animals and plants, probably by osmosis; through the stomata and lenticels of higher plants; through the breathing pores of insects; and through the gills and lungs of more complex animals.

This chapter will deal in general with the whole subject of the elimination of wastes; but it will discuss chiefly the excretion of water, of nitrogenous[1] wastes, and of other products of metabolism.

Self-test. 1. Waste products are *usually* formed when food is oxidized.

2. Excretion is made necessary by *metabolism*.

3. The chief waste products resulting from metabolism are --?--, --?--, and --?--.

4. Carbon dioxide leaves the body through the --?--; solid wastes are eliminated from the --?--; other waste products are dissolved in *water* which is eliminated.

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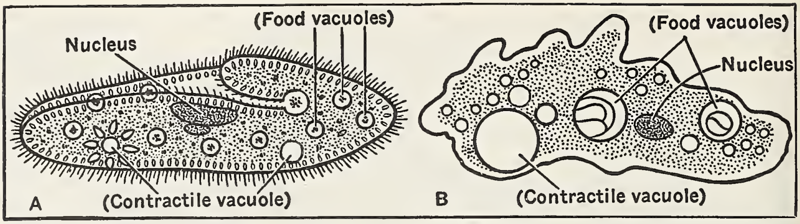
[1] *Nitrogenous* (nī trŏj'ē nŭs): composed partly of nitrogen.



Can you explain these diagrams, showing excretion in (A) *Paramecium* and (B) *Amoeba*?

HOW IS EXCRETION CARRIED ON IN TYPICAL PLANTS AND ANIMALS?

Excretion in plants. Urea and the other waste products of cell activities are soluble in water. Hence they are largely eliminated with the excess water. In the lower plants excretion of such products is effected through the cell walls. In the higher plants most of the organic wastes enter the sap from each cell and are carried through the vascular system to other parts, particularly to the roots, where they can be eliminated. In certain cases some of the wastes may be transformed into crystals and left in the leaves or stems.

If the organic wastes which are eliminated from the roots are not later carried away from the roots by the soil water, the plant dies. It will be seen that in higher plants and, as we shall see later, in higher animals the vascular system is as necessary in removing waste products from all the living cells as it is in bringing them food, oxygen, and other necessary materials.

Excretion in typical animals. Having no digestive system *Amoeba* gets rid of undigested materials by simply moving away and leaving them behind. It eliminates excess water and with it urea and perhaps other organic compounds in solution, thus: In the single-celled body of an amoeba is a bubble-like cavity (contractile vacuole). At fairly regular intervals this cavity fills with water from within the cell, increasing in size as it does so. Then the protoplasm around the cavity contracts, forcing the water with its dissolved waste compounds out of the cell.

Paramecium has two of these spaces, or special cavities (contractile vacuoles), for eliminating water and dissolved cell wastes. One is located at each end of the body. Each is connected with a number of smaller cavities which extend from it like the spokes of a wheel. Water enters these small cavities from the protoplasm. When they are full, they contract, discharging their contents into the larger cavity. When this in turn is full, it discharges outside.

The earthworm has simple organs of excretion. These consist of a pair of slender coiled tubes (nephridia) in almost every segment of the animal. These tubes extract urea and other wastes from the blood.

The grasshopper, like all other insects, has many small tubes (Malpighian tubes) of considerable length extending throughout the body. These collect urea and other products of excretion from the blood and empty these waste substances into the digestive tube through openings at the beginning of the small intestine.

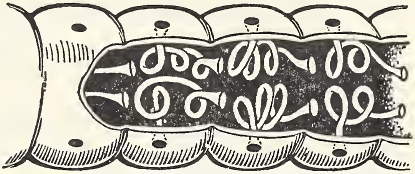


Diagram showing the general structure and the location of the excretory organs of an earthworm. How does the means of excretion in the earthworm mark an advance over those in animals lower in the scale of life—for example, the protozoans and the sponges?

Some recent investigations seem to indicate that the molting of insects serves as a means of excretion. In these experiments insects that had been starved continued to molt, though their bodies no longer filled their exoskeletons.

Though lower in the scale of life than the grasshopper, the clam has a somewhat more complex excretory system. It has an organ of excretion on each side of the body. Each of these organs consists of a U-shaped tube. One end of the tube is a simple kidney. Both the tubes and the kidneys extract urea and other wastes. The other end of the tube is a thin-walled bladder. Both the wastes stored in the bladder and those from the intestine are carried out of the body through the same opening.

The fish, a more complex animal, has two more complex kidneys. These kidneys contain many tubes which extract urea and other organic wastes from the blood. These wastes are stored in a bladder. A tube carries the wastes from the bladder out of the body at a point just back of the opening (anus) from the intestine (see figure, p. 210).

In all the higher animals both the liver and the skin are organs of excretion, as will be explained.

Summary of general facts about excretion in plants and animals. *Excess water in living things always contains in solution waste products resulting from cell activities. This excess water is eliminated from the simpler organisms chiefly by osmosis through the cell walls. In the higher animals these waste products are eliminated from the cells into the blood. They are carried through the circulatory system by the blood to special organs. These separate the waste products from the blood and get rid of them.

*The excretory system in its simplest form is merely a system of tubes running through the tissues of the body and emptying either outside the body or into the digestive system. In higher animals these tubes are not located in various parts of the animals. Instead they are grouped together in the kidneys, through which the blood carrying the wastes passes. The excess liquid containing the nitrogenous wastes passes from the kidneys into the bladder. In the highest animals the excretory system consists (1) of the kidneys and bladder with the tubes leading from them, (2) of the liver, and (3) of the skin.

Self-test. 1. When higher plants shed their leaves, they get rid of some --?-- wastes.

2. The Protozoa have *rudimentary* organs of excretion.

3. The earthworm has *one pair* of excretory organs.

4. Some scientists believe that insects excrete some of their organic wastes by the action of simple excretory organs and the rest by means of shedding their --?--.

5. A simple kidney and a urinary bladder are found as low in the scale of life as the --?--.

6. In the higher animals the *bladder* extracts wastes from the blood; these wastes are stored in the *kidneys* until they can be eliminated.

Self-test on Organization of Facts. In this section the advance toward a more complex excretory system in the animals described were these:

No organs, but definite points in the single-celled body where the solid and liquid wastes are eliminated.

Osmosis: forcing out liquid wastes through any portion of a cell wall; moving away and leaving the wastes behind.

More highly specialized organs of excretion: kidneys, bladder, and liver.

Division of labor: simple organs of excretion; many pairs of slender coiled tubes for collecting excess water and urea.

Instead of many pairs of tubes, one pair of complex tubes.

Can you arrange these in order of increasing complexity and name the animal or animals which illustrate each of these advances? Can you name the phylum to which each animal belongs?

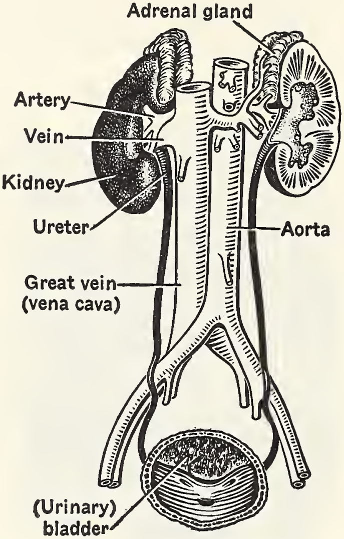
HOW IS EXCRETION CARRIED ON IN MAN?

Changing nitrogenous wastes. As has been stated, the energy foods are carbohydrates, fats, and proteins. Unlike the fats and carbohydrates, however, the proteins serve not only as fuel but also as material for building and replacing protoplasm. If more protein is eaten than is needed for growth and replacement of protoplasm, the rest is used as fuel. By the process of digestion, proteins are changed to amino acids. All amino acids contain nitrogen. The nitrogen portion of the amino acids cannot be burned in the cells. Hence a chemical change takes place in which the nitrogen portion of the amino acids is thrown out as waste, and the remainder is burned in the cells as fuel. All living cells can thus change amino acids into fuel by separating the nitrogen portion from the rest.

These nitrogenous wastes are in the form of ammonium compounds. They are poisonous in the blood unless they are in extremely small quantities. They must therefore be changed immediately into urea, which is harmless in the blood if it does not become too highly concentrated. All living cells can change the poisonous ammonium compounds into urea. Making this necessary chemical change is also an important function of the liver.

The liver an organ of excretion. Ammonium compounds which have not been changed to urea in the cells are carried in the blood to the liver. Here they are changed into urea and thus made harmless. The urea produced by the cells and by the liver passes into the blood, which carries it to the kidneys. The kidneys separate the urea from the blood and eliminate it.

The liver performs important excretory functions other than that of changing nitrogen compounds to urea. In Chapter XVII we learned that the liver breaks up worn-out red corpuscles and excretes the waste materials as part of the bile.



The human kidneys. What excretory organs are not shown in this figure?

The urinary organs. The urinary organs consist of the kidneys, the bladder, and the tubes leading from the kidneys to the bladder and from the bladder outside the body.

Experiment 54. What are the characteristics of a kidney? Examine a pig's, a calf's, or a sheep's kidney. Can you find where the blood vessels enter and leave the kidney? Can you find the tube (ureter) through which the urine passes from the kidney? Cut the kidney in half lengthwise. Describe the structure in a brief paragraph. Use sketches to help make your meaning clear.

The human kidneys are two bean-shaped organs about four or five inches long. They are located one on each side of the body near the small of the back. They are composed largely of blood vessels and of small tubes which are very close to the blood vessels.

*The kidneys purify the blood by removing from it urea and other substances, including excess water, which are not needed by the blood. How the kidneys perform this function is not yet known. The product of the action of the kidneys is urine. Urine is made up of about 96 per cent water and 4 per cent dissolved solids. In each kidney urine passes from the small tubes into larger ones and finally into the large one (ureter) leading to the bladder. This is a bag-like organ in which the urine collects for a time and then is eliminated from the body through another tube (the urethra).

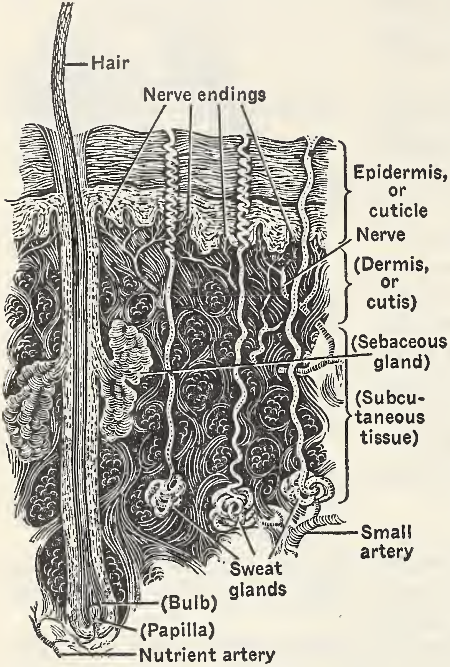


Diagram of skin structures. What functions besides excretion does the skin have?

The skin. *The outer layer, or epidermis, of the skin is composed of dead cells. The epidermis covers and protects the living cells beneath. Sweat glands are distributed over the body, to the number of more than two million. They are most numerous in the palms of the hands and the soles of the feet. They assist the kidneys in getting rid of excess water in the blood. These glands consist each of a long coiled tube leading to an opening, or pore, in the skin. Water containing waste materials from the blood passes from the capillaries into this tube and through it to the outside. Several pints of sweat (perspiration) may be eliminated in one day. In addition to water the sweat consists of inorganic salts, chiefly common table salt (sodium chloride). It also contains smaller quantities of urea and of other organic substances.

The chief function of sweat, however, is not to get rid of wastes but to regulate the temperature of the body by its evaporation. You will recall that heat is produced by the combustion of energy foods in the cells and by the friction of the muscles. Our bodies must always remain at a temperature of about 98.6° F. Hence excess heat must be eliminated. Heat is lost from our bodies in several ways: (1) by being eliminated with the products of excretion, since these waste products when eliminated are at the same temperature as the body; (2) by being used in changing water to vapor in the lungs; (3) by being eliminated with the air which is breathed from the lungs; (4) by being used in evaporating sweat from the skin; (5) by escaping from the skin. About two thirds of the excess heat is removed by the last means, and more than half of the remainder by the evaporation of sweat.

Self-test. 1. Ammonium compounds in the blood must be changed into --?--.

2. The liver functions in changing --?-- compounds, which are carried to it in the blood, into urea.

3. The kidneys extract from the blood --?-- and other wastes.

4. Waste materials from worn-out red corpuscles are eliminated through the *alimentary canal.*

5. The kidneys are assisted by the --?-- in eliminating urea and other wastes.

6. The chief function of sweat is to *eliminate wastes.*

7. Name four ways in which our bodies lose heat.

Self-test on Organization of Facts. List from this and preceding chapters all the organs which have to do with removing wastes from the body. Name the wastes removed by each.

Self-test on Important Biological Terms

bladder
excretion
kidney
metabolism
sweat gland
urea

Self-test on Biological Principles. What evidence can you state from this chapter that complexity of structure is accompanied by an increase in division of labor?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why does fanning oneself help to keep one cool?

2. How does drinking a sufficient amount of water help the kidneys to do their work?

3. In what way is the blood which leaves the kidneys different from the blood which comes to them?

4. A case is known of a man who had no sweat glands. In summer he could do no work of any sort. Explain.

CHAPTER XX

Control of the Body by Glands

Questions This Chapter Answers. 1. How do glands take part in the division of labor? · 2. What kinds of glands function in plants and animals? · 3. What is the nature of hormones? · 4. What are the nature and the important functions of the endocrine glands in man?

WHAT ARE SOME FUNCTIONS OF HUMAN GLANDS?

Division of labor in the work of cells. One of the most interesting features of every circus is its side show. It is an unusual side show which does not exhibit a man or a woman who is remarkable for being exceptionally fat, thin, short, or tall. It was not discovered until fairly recently, however, why these people were so different from normal people. Now it is known that "The World's Fattest Man," "Tom Thumb," huge and tiny people, and all others of these types of circus "freaks" are, with few exceptions, unfortunate people who have certain glands which are not functioning properly. Consequently their growth and development are not normal. Let us now consider what glands are and what they do.

You have learned from preceding chapters that every living cell is a chemical laboratory. This statement is true in the sense that raw materials are taken in, chemical changes take place, certain useful products are formed, and waste materials result. Thus every living cell carries on part of the work of metabolism. Certain cells, however, not only carry on the usual cell activities, but also produce special substances needed by the body. These cells are grouped in special structures called glands (see diagrams on page 404).

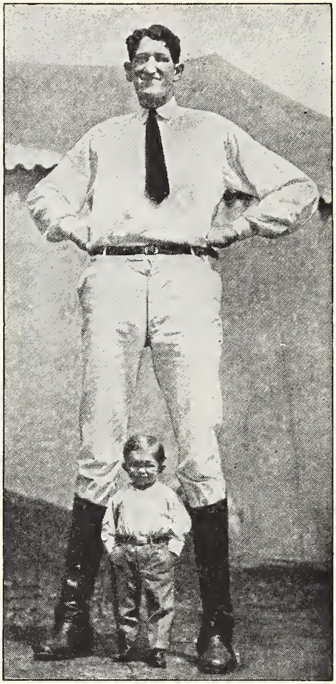
Kinds of glands and their functions. Glands are found in all but the simplest plants and animals. They are of two kinds: (1) the duct glands, or glands of external secretion, and (2) the endocrine glands (or glands of internal secretion, called also ductless glands). The duct glands pour out their secretions through tubes, or ducts. The endocrine glands have no tubes or ducts; hence their secretions pass directly into the blood stream.

The simplest glands are merely single cells. The mucous cells of the villi are single-celled glands of the duct type. Many-celled glands are of a variety of forms. Some special glands in plants manufacture perfumes, flavors, waxes, and gums. Glands in animals manufacture such familiar substances as digestive juices, egg shells, shells which serve to cover the animal, milk for the young, and poisons for protection.

Many of the glands have been known for centuries. But until recently practically nothing was known of the endocrine glands except their location in the body. Today many scientists are engaged in studies concerned with the functions of these glands. Some study of endocrine glands has been made in animals as low in the scale of life as fish and even among the invertebrates. This chapter, however, will discuss only some of the more important endocrine glands and their special functions in human beings.

Human endocrine glands and their functions. Endocrine glands are located in various parts of the body. Some of them are very small—not larger than a pea. The endocrine glands include the thyroid gland and the parathyroid glands, located in the neck; the thymus gland, located in the upper part of the chest; the pineal gland and the pituitary gland, both located in the head and surrounded by the brain; the adrenal (sometimes called the suprarenal) glands, on the kidneys; certain portions of the pancreas (called the islands of Langerhans). Certain cells of the reproductive organs also function as endocrine glands.

The secretions of these glands, called hormones, pass into the blood stream and are carried by it to every part of the body. They influence and regulate the growth and development of the body; the metabolism of food, minerals, and water; and the development and activity of the reproductive organs. Their activities exert considerable control over the rate of growth, the height and the general build of the body, the time at which one will mature, and how fat one will probably become. They share in the control of digestion, the circulation of the blood, the regulation of blood pressure, and the activities of the nervous system. Each of the glands has its own special functions; yet all work more or less together as a connected system.

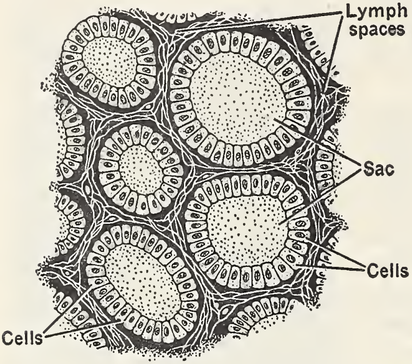


H. A. Atwell, Studio

Extreme tallness or extreme shortness is sometimes due to a defective condition of which gland?

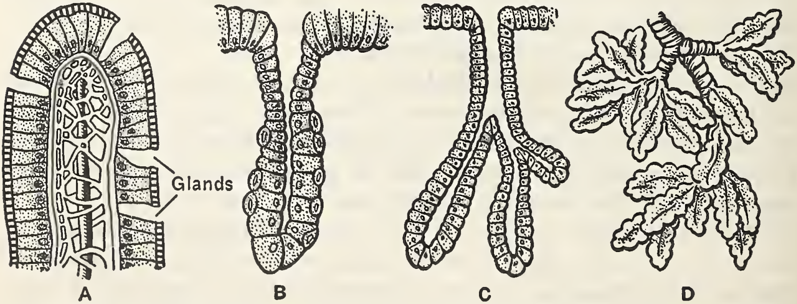
The thyroid gland. The thyroid gland consists of two dark-red lobes, one on each side of the windpipe, joined by a strip of tissue. The most important secretion of this gland is a hormone (thyroxine) which is composed of about 60 per cent iodine. Serious consequences result when too little or too much of this hormone is produced. Too little may be formed because the food eaten does not furnish a sufficient supply of iodine salts to serve as raw material for the building of the hormone. When this condition occurs, the thyroid enlarges, causing the swelling at the base of the neck called simple goiter. When, because of an inherited defect, the gland is unable to secrete a sufficient quantity of the hormone, the child fails to develop normally either physically or mentally. Another result of the failure of the thyroid gland to secrete a sufficient quantity of its hormones in later life is that a person often becomes very dull, inactive, and fat. The skin becomes swollen, the hair may fall out, and the person becomes very sensitive to cold.

Sometimes the conditions caused by a deficiency of the thyroid hormones can be overcome in children and can be improved in adults if the sufferer is given thyroid extract. Taking this extract, however, is not a cure, since the extract cannot correct the defect in the gland itself. The sufferer must continue the treatment as long as he lives.



Endocrine glands. The cells secrete hormones into the closed sacs which they surround. The internal secretion then slowly finds its way out between the cells into the lymph. How do the secretions then reach the various parts of the body? (You may need to review portions of Chapter XVII)

If too much of this thyroid hormone (thyroxine) passes into the blood stream, a serious disease (hyperthyroidism, sometimes called exophthalmic



Some typical duct glands. Is the sweat gland (p. 400) a simple or a complex gland? Explain goiter) results. This is often successfully treated by surgery in which a part of the over-active thyroid gland is removed.

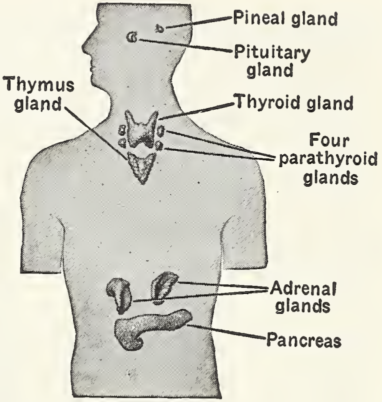


Diagram showing the location of various glands. All glands have a rich blood supply. Can you explain why this rich blood supply is necessary?

An interesting experiment which shows that the hormones of the thyroid gland influence the development of a young animal has been performed with frog tadpoles. If the tadpole is fed thyroid extract, it develops very rapidly and becomes an adult in much less time than does a normally fed tadpole. But if the thyroid glands of a tadpole are removed, the tadpole never develops into a mature frog.

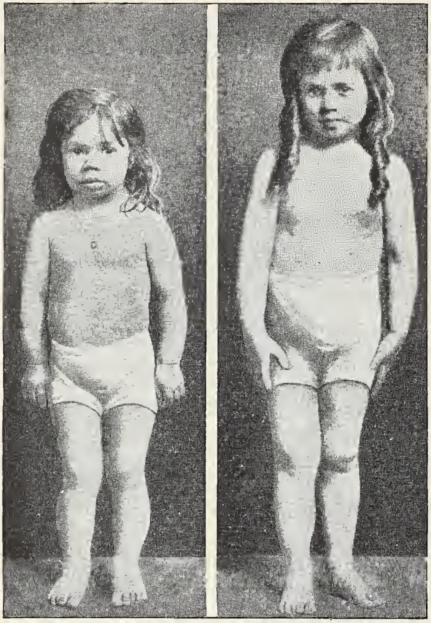
The parathyroid glands. There are usually four parathyroid glands, although there may be as many as twelve. They are buried in the tissue of the thyroid gland. The parathyroid glands produce hormones which control the assimilation and excretion of lime and phosphorus. Thus they affect the development and the structure of the teeth and bones. The hormones also affect the nervous system. If the parathyroids are accidentally removed in a goiter operation, severe nervous shock results.

The pituitary gland. The pituitary gland is mainly composed of two lobes. Each consists of a different sort of tissue from the other, and each has a totally different function from the other.

The anterior lobe is sometimes called "the master gland," because its secretions control a number of the other endocrine glands. Although scarcely larger than a pea, it produces at least six different hormones. These affect the metabolism of food and influence growth. If too much of the growth hormone is produced, the person may grow to be a giant like those in the circus side shows. If too little is produced, the child may be a dwarf. In this case, however, unlike dwarfs produced by an insufficient amount of the thyroid hormone, he may be perfectly proportioned.

The rear, or posterior, lobe produces several hormones the best known of which (1) affect the activity of the kidneys and (2) regulate the muscles of certain internal organs.

The adrenal glands. Each adrenal gland is composed of an outer shell, or cortex, which surrounds the inner portion, or medulla. Both secrete important hormones. The hormone adrenalin (or adrenin, or epinephrine) is produced by the medulla. It has marked effects especially upon the liver, certain muscles, and the circulatory system. When one is frightened, angry, or excited, the medulla supplies to the blood an unusually large amount of adrenalin. Adrenalin acts upon the liver, causing it to change some of its stored animal starch, or glycogen, into sugar and to pour this into the blood stream. Thus an additional energy supply is available in case it is necessary to run, to fight, or to engage in unusual exertion. Adrenalin also causes a more rapid heartbeat and a greater blood pressure. At the same time it stops the digestive processes, thus sending more blood to the muscles and brain for use in the emergency. The result is that one is capable of muscular feats which ordinarily could not be accomplished.


Two photographs of the same child, a cretin, before and after a period of treatment. All children who suffer thus from lack of thyroid hormones have the same general appearance and characteristics as those shown in the first picture. Can you suggest how the change was brought about?[1]

Adrenalin has been analyzed by chemists and can be made artificially from coal tar. The commercial product, however, is obtained from the adrenal glands of cattle. It is used in surgery (1) to check excessive bleeding, (2) to stimulate heart action, (3) to reduce the effects of shock or to prevent the collapse of a patient after an operation, and (4) to relieve asthma.

The cortex of the adrenal gland produces a fat-like hormone (cortin) which is essential to life. When too little of the hormone is produced, the person becomes extremely weak, with very low blood pressure; the skin becomes very dark; and death occurs unless some of this hormone is injected into the blood.

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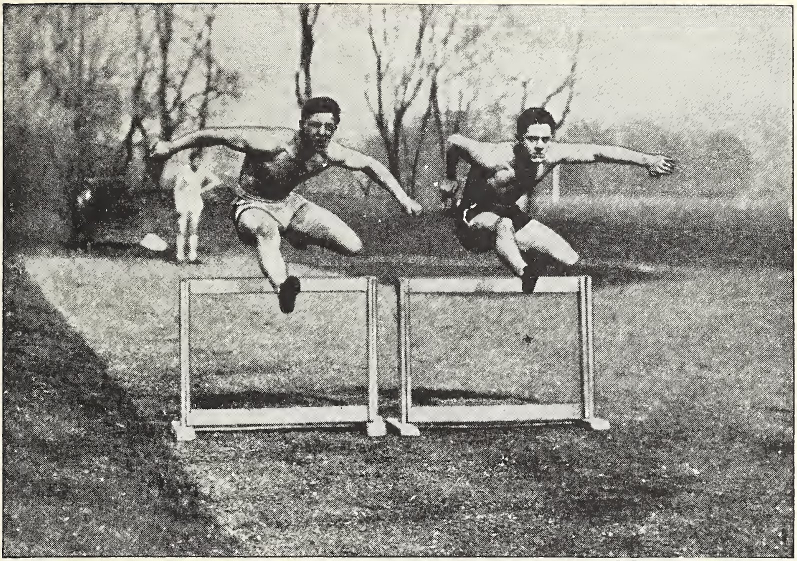
[1] From N. B. Foster, "Diseases of the Thyroid Gland," in *Nelson Loose-Leaf Living Medicine*, Vol. III, by permission of Thomas Nelson & Sons.



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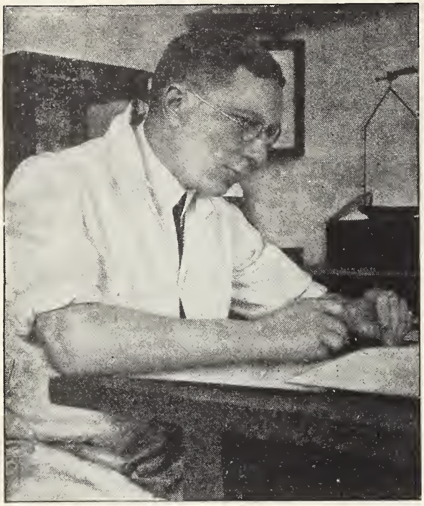
The supreme effort put forth in athletics is helped by the secretions of what gland?

The pineal gland. Some of the early investigators regarded the pineal gland as the seat of the human soul because it is located between the two halves of the brain. In some of the lower organisms this gland is developed into a rudimentary third eye. It is believed that this third eye was more perfectly developed in certain mud-burrowing creatures which became extinct millions of years ago. The functions of this gland in man are not yet clearly understood.

Thymus gland. The thymus gland is found at the base of the neck just within the chest cavity. The functions of this gland are not well known. It seems to have a definite influence on the normal growth and development of the body. The gland decreases in size as a child becomes older, and usually has practically disappeared in an adult.

Organs which contain both duct glands and endocrine glands. *The pancreas.* The pancreas was discussed in the chapter on digestion as an important digestive gland. It secretes certain enzymes which flow through its ducts into the small intestine, where they digest starches, proteins, and fats. However, certain cells of the pancreas (the islands of Langerhans) have an entirely different function, that of manufacturing insulin. Insulin does not leave the pancreas through ducts. It passes directly into the blood, as do the secretions of the endocrine glands just discussed.

Insulin controls the amount of sugar used by the cells of the body. It will be remembered from the discussion of circulation that digested carbohydrates pass into the blood as sugar. Passing with the blood to the liver, the excess sugar is stored in this organ as animal starch, or glycogen, to be changed back again into sugar when needed. Insulin acts upon the liver to prevent it from changing its reserve starch into sugar when there is already sufficient sugar in the blood for the use of the cells. Insulin not only thus controls the amount of sugar in the blood, but also makes it possible for the cells to use sugar from the blood.



Dr. F. G. Banting. **Special Report:** The use of insulin in the treatment of diabetes

The disease diabetes results when the pancreas fails to supply the blood with a sufficient amount of insulin. The liver cannot then store glycogen properly. Instead the glycogen passes into the blood as sugar. Moreover, when there is too little insulin in the blood, the cells cannot assimilate the sugar which the circulation brings to them. The result is that the blood has an excess of sugar, which is excreted by the kidneys.

Until recently there was no lasting help for one suffering from diabetes, except through control of the diet, chiefly by limiting the foods that supplied sugar. The disease was frequently fatal. In 1924 two Canadian scientists, Banting and Best, succeeded in preparing insulin from the pancreas of lower animals. When this insulin is injected into the blood of a person who is suffering from diabetes, it functions just as if it had been manufactured by the pancreas in his own body. He is thus able to use the sugar in his body.

The insulin treatment is not, however, a cure for diabetes. It does not remove the cause of diabetes by restoring the pancreas to its normal activities. If the deficiency of the pancreas is permanent, the sufferer must continue the treatment as long as he lives.

The small intestine. The cells of the upper part of the small intestine pour digestive juices into the intestine. At the same time they manufacture hormones. These start the digestive processes in the small intestine, thus: The food which leaves the stomach is acid in character, from the hydrochloric acid of the stomach. When this acid material comes in contact with the intestine cells, these secrete a hormone (secretin) into the blood. This hormone is carried by the circulation to the pancreas. It stimulates the pancreas to secrete and to pour into the intestine the enzymes needed for the further digestion of the food.

The reproductive organs. The products of the reproductive organs make possible the survival of the race. These organs, however, have other important functions. Certain groups of cells buried among the reproductive cells, and controlled by the pituitary gland, secrete hormones into the blood. These cells become active at about the time when a person approaches adolescence, or the period when one begins to develop rapidly into a mature man or woman. The hormones produced by these cells control the development of the male or the female characteristics.

There is no definite age at which a person reaches adolescence. This period may begin at any time between the ages of nine and fifteen. Adolescence continues for several years. During this time the hormones secreted by the reproductive glands produce marked changes in the body. The boy or the girl usually gains rapidly in height and weight. Often the young person passes through an "awkward age," when he finds it difficult to control his rapidly growing body. The vocal cords of a boy lengthen considerably, with the result that finally he has the deeper voice of a man. Also, the young man begins to develop a beard. During adolescence many young people are troubled with a bad complexion. This difficulty, however, often disappears after they have become fully mature.

Self-test. 1. *All* plants and animals have glands.

2. *Endocrine* glands manufacture secretions which they pour out through tubes; *duct* glands manufacture secretions which they pour directly into the blood stream.

3. The secretions of the various endocrine glands are called (1) hormones; (2) electrons; (3) enzymes; (4) endocrines; (5) insulins; (6) thyroxine.

4. Match each word or expression under *B* with one of those under *A*.

A

a. Gastric
b. Thyroid
c. Parathyroid
d. Pineal
e. Lymphatic
f. Pituitary
g. Adrenal
h. Pancreas
i. Glands of small intestine

B

1. Influence the pancreas
2. Extreme tallness
3. Assimilation of lime and calcium
4. Goiter
5. Diabetes
6. Releases energy needed in an emergency

Self-test on Important Biological Terms

duct gland
endocrine gland
gland
hormone
secretion

ADDITIONAL EXERCISES AND ACTIVITIES

Problem. A number of glands were discussed in the preceding chapters dealing with the physiological processes of plants and animals, especially of man. How many of these glands can you name and locate? Of how many of them can you briefly describe the special work, or function?

Special Reports. **1.** Find out all you can about the discovery of insulin. (Consult a physiology textbook or an encyclopedia.)

2. Secure further information about any one of the endocrine glands which especially interests you. (Consult a physiology textbook or an encyclopedia.)

3. Find, in zoology or physiology textbooks, examples of each of the four types of glands in the figure on page 404.

4. The use of the X ray in relation to the thymus gland in new-born babies. (Consult your family physician.)

5. Find out from your family physician under what conditions and in what forms adrenalin and thyroid extracts are given to people needing them.

Exercise on Scientific Method and Scientific Attitudes. Which of the elements of scientific method were used by Banting and Best in their study of diabetes? Which of the scientific attitudes is it certain that they possessed?

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Respiration. Eastman Kodak Company, Rochester, New York.
The Digestive Tract. Eastman Kodak Company, Rochester, New York.

Review Exercise on Scientific Principles. The following principles have a direct relation to the Second World War and to the postwar period. Can you explain how each principle applies to the war? Which apply also to the postwar period? How? Which of these principles are not stated on pages 626 and 627?

All organisms must have energy in the form of food.

All organisms must have water in order to survive.

Living things have become adapted to wide ranges of physical conditions.

Certain associations of animals are the result of a struggle for survival.

The energy which makes possible the activities of most living things came first from the sun and is secured by the organism through the oxidation of food within the body.

All living things have living enemies which compete with them for available energy.

Plants and animals are dependent on one another in various ways.

The work of chlorophyll is essential to all living things.

The environment acts on living things, and living things act on their environment.

Living things are engaged in a constant struggle for energy.

Protective adaptations are an aid to survival.

When the environment changes, an animal must adjust itself to the change or migrate or fail to survive.

A reaction is successful if, directly or indirectly, it aids an animal to survive.

Many organisms survive because they are able to build artificial shelters.

Those organisms are most likely to survive that are best fitted to their environments.

Plants and animals depend directly or indirectly on the soil.

UNIT VI · THE RESPONSES

Suppose on a visit to the zoo we were to blow a shrill whistle in front of every cage or pen. What would the animals do? We could accurately predict the ways in which many of them would behave. Many of the birds would probably show fright. The lion could be expected to look intently about. Perhaps the monkeys would approach as near to us as they could. The buffalo and the antelope would be likely also to indicate that they were curious, but would probably not run away. The snakes would be almost certain to do nothing.

OF LIVING THINGS

The responses which living things make to sights, sounds, heat, and other influences are closely related to the struggle for survival. A deer, for example, could not long escape capture by a wildcat, nor could a wildcat ever capture a deer, unless it could respond to sights, sounds, and odors. Also, responses are closely related to our pleasures. We could not, for example, enjoy a football game, a radio program, or the smell of a good dinner if we could not respond to changes in the environment. This unit discusses why and how living things behave as they do.

CHAPTER XXI

Unlearned Responses

Questions This Chapter Answers. 1. How are living things affected by various influences or conditions in their surroundings? · 2. What kinds of responses to influences in the environment are made by plants and animals? · 3. How do special sense organs aid various animals in the struggle for survival? · 4. What is the structure and what are the functions of the human nervous system?

WHAT ARE THE SIMPLEST TYPES OF RESPONSES?

Responses to stimuli. Some years ago an expedition from the United States went, with the permission of the Netherlands government, to the island of Komodo to secure some of the "dragons" (see the figure on page 66) as specimens for the New York Zoological Gardens. They set a powerful trap which would catch the animals alive and unhurt and baited it with raw meat. From a safe distance, for the animals are dangerous, an observer watched to see what would happen.

Soon one of the animals approached the trap. But it seemed suspicious, for it remained motionless for almost half an hour, gazing into the forest, evidently very watchful. Finally, seeing nothing that alarmed it, it yielded to the temptation offered by the bait, entered the trap, and, in spite of heroic struggles, was captured.

The behavior of the dragon was a series of responses to changes in its environment—the presence of the trap, the tempting bait, and later the sprung trap. The ability to respond to all sorts of changes in the environment is one of the differences between living and non-living things. All living things, both plants and animals, have this ability. Non-living things are not affected by such changes and cannot of themselves react[1] to them. Therefore only living things are irritable; that is, only living things react to touch (or contact), light, sound, electricity, changes in temperature, and various other stimuli. A reaction is a successful one if it aids the organism to survive. The reaction of the dragon of Komodo to the stimulus of the bait was not a successful one. Later, however, when the animal responded to the stimulus of being shut up, by tearing a great hole in its cage and escaping, its reaction was a successful one.

Living things differ in the kinds of stimuli to which they are able to respond. Your dog may come when you call him. But an earthworm could not respond to the stimulus of sound, because it has neither organs for hearing nor the sort of brain by which it could understand even if it could hear. A wolf would be able to smell meat when too far away to see it. But such a meat-eating bird as a vulture would need to see the meat in order to find it.

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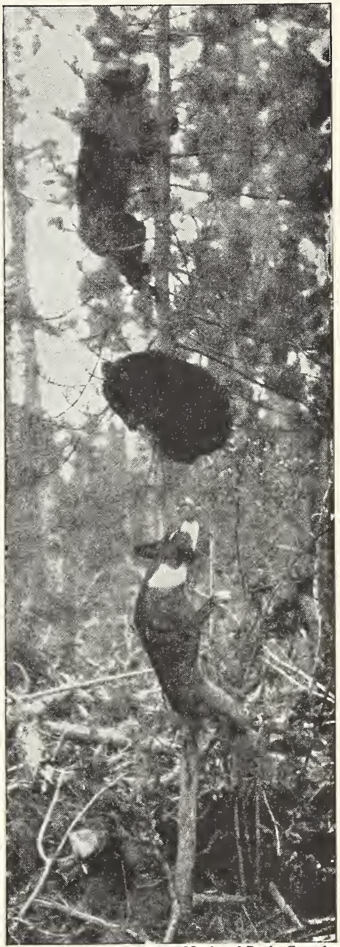
[1] *React* (rē ăkt′): to act in response to a stimulus. The response to a stimulus is a *reaction* (rē ăk′shŭn).

Different sorts of living things may react to the same stimulus in very different ways. A cat would show no interest in a fishing pole but probably would want to eat a raw fish. A boy, however, would probably be enthusiastic over a fishing pole, but would not be interested in a raw fish as food.

Responses of plants to stimuli. The responses of plants to stimuli of various sorts are less pronounced than those of most animals. Also, there are fewer stimuli to which plants can respond. All but the simplest plants, however, have some structures which are especially adapted to receiving stimuli. An experiment will indicate how plants react to the stimulus of gravity.



Jasper National Park, Canada

How is irritability illustrated here?

Experiment 55. Does gravity always influence roots to grow downward? Make a "pocket garden" in the following manner: Secure two pieces of glass about five inches square. On one place several layers of blotting paper, paper toweling, cotton, or other material that will hold moisture. Wet this material thoroughly. Then on the wet paper put four or more corn or oat grains or other seeds which have soaked for several hours. Cover these with the second glass square and fasten the entire apparatus securely together by putting gummed tape or paper around the edges. Stand the "pocket garden" on edge and examine it from day to day. Keep it moist. When the seeds begin to germinate, note whether or not the roots all grow downward. Turn the garden completely over, standing it on the opposite edge from that on which it first rested. Do the roots continue to grow in the direction in which they started, or do they again turn downward? In what direction do the stems grow?

Several seeds were used in this experiment instead of one, to provide controls (see "Elements of Scientific Method," page 625). Explain.

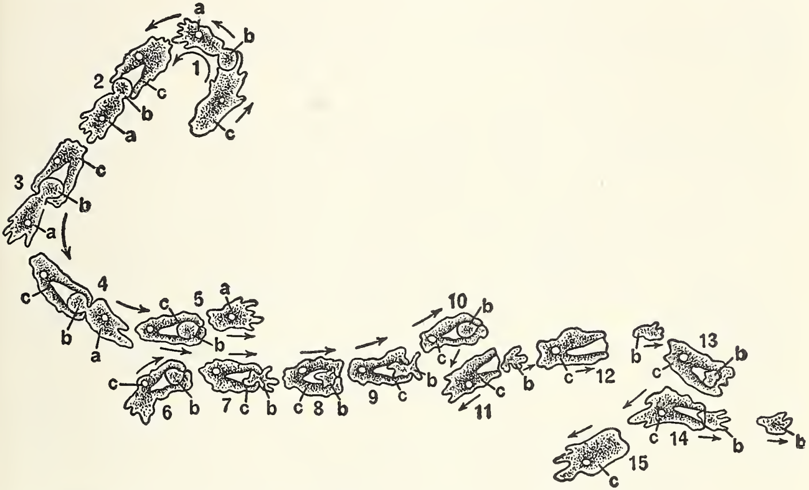
What statement in the text does this picture illustrate?

As was stated earlier, no organism can continue to live long without securing water. Water, therefore, provides a stimulus to which all living things respond. Thus most plants show a marked tendency to send roots in the direction of water. Alfalfa grown in dry regions has been known to produce nearly vertical roots fifteen feet long. In our city streets drain-pipes are sometimes choked or burst by roots which grow through cracks in the pipes in their search for water. Some cities prohibit the planting of such trees as poplars because of this tendency.

Light is another stimulus which causes a plant to behave in a certain way. The tips of many plants turn so as to face the sunlight. Some plants exhibit responses to darkness or to decreasing light. Thus the flowers of morning-glory, dandelion, and primrose close at night. Also, the leaves of some kinds of clover fold together and droop along the stem.

Responses of Protozoa. Although Protozoa have no special organs for receiving stimuli or making responses, they respond to a variety of stimuli in definite ways which normally do not vary. If, for example, an amoeba is touched, it contracts and remains motionless for some time. When it encounters a bit of material that might serve as food, the protoplasm flows around the particle and takes it in. If one side of a drop of water containing an amoeba is strongly heated, the animal moves away from the warmer part.

An amoeba will also move away from a bright light thrown on the water. Apparently the animal is sensitive to chemical changes too, for it will retreat from a drop of salt water. Other Protozoa have reactions more or less like those of an amoeba. *Paramecium* will swim away from a drop of salt water, but will swim into a drop of weak acid and stay there.



An unexplained response. The behavior of even the simplest animals is sometimes amazing. Jennings, a prominent American biologist, observed a large amoeba pursue a smaller one and finally succeed in pinching off and surrounding part of it. Several times the part swallowed tried to escape through an opening in the protoplasm of the larger one, but each time was prevented by the surrounding movements of the latter. Finally it succeeded in escaping completely, only to be pursued and again captured. The small bit of amoeba then contracted into a ball and stayed still until, in crawling about, the larger one left only a thin layer of protoplasm covering it. The prisoner then quickly forced its way through the thin wall and escaped. In accepting the account of these observations, which of the scientific attitudes (p. 624) do scientists illustrate?[1]

Simplest reactions called tropisms. The kinds of reactions of plants and one-celled animals which have just been described are called tropisms. A *tropism* is the simplest reaction to a stimulus. It is not an act which the organism has learned to perform or can learn to perform. The organism inherits the ability to react in a certain way to a certain stimulus. It normally reacts in no other way to that same stimulus.

The word *tropism* means "a turning." Hence a tropism is the turning of part or all of the organism toward or away from the influence, or stimulus. If the organism or a part of it moves toward the stimulus, the tropism is a positive one. If the movement is away from the stimulus, the tropism is a negative one. Thus plant roots have a positive tropism toward the earth and toward water. Plant stems have a negative tropism toward the earth and a positive one toward light.

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[1] After Jennings's *Behaviour of the Lower Organisms.*

The plants and the simplest animals can make no responses other than tropisms.[1] But more complex animals, even some as high in the scale of life as birds, have tropisms. For example, if a captured wild bird is given its freedom in a room, it will usually fly directly to a window.

If in avoiding an unfavorable stimulus the organism happens to reach a place where the conditions are more favorable to its life, it survives. But if it happens to reach an environment which is unfavorable, it may die. In general, however, tropisms have survival values for the organisms performing them. For example, an amoeba avoids stimuli such as extreme heat and strong chemicals, which might injure it, and moves toward food. Sometimes, however, the tropism results in the death of the organism. Sea birds flying after sunset near a lighthouse sometimes fly straight toward the light, killing themselves against the lamp tower. Wild geese and ducks and other birds flying at night sometimes fly against the lighted windows of tall buildings.

Experiment 56. Do certain animals, such as millepedes, spiders, or beetles, show a positive or a negative tropism toward light? Place the animal in a darkened space of which some parts are darker than others. Turn the light from a flashlight upon the animal and watch its reaction. Answer with a complete sentence the question asked at the beginning of this experiment.

Self-test. 1. An animal is irritable if it (1) gets angry easily; (2) scratches itself; (3) is partly deaf; (4) changes its behavior in accordance with changes in the environment; (5) carries on the process of metabolism.

2. The *leaves* of most plants grow in the direction of water.

3. It is *difficult* for any living thing to learn to perform a tropism.

4. Trees and flowering plants have *few* reactions other than tropisms.

5. Tropisms are *seldom* an aid to the survival of an organism.

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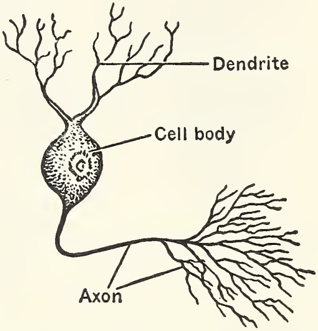
[1] Among the different tropisms are these: (1) chemotropism, a reaction to some chemicals; (2) electrotropism, a reaction to electric current; (3) phototropism, a reaction to light; (4) heliotropism, a reaction to the sun; (5) thigmotropism, a reaction to contact; (6) thermotropism, a reaction to heat energy; (7) geotropism, a reaction to gravity; (8) rheotropism, a reaction to a current of water; (9) chromotropism, a reaction to color; (10) hydrotropism, a reaction to water. Some recent investigations give results which seem to indicate that tropisms are negative and that a turning toward a stimulus is really a turning away from the opposite stimulus. Thus what would seem like a turning toward light would be a turning away from darkness.

HOW DO ORGANISMS WITH NERVOUS SYSTEMS REACT TO STIMULI?

Nervous systems composed of cells. In the case of plants and the one-celled animals, the organism as a whole or a considerable portion of it receives the stimulus and reacts to it. Most of the many-celled animals, however, have certain cells, called nerve cells, or neurons, which are specially fitted for receiving impressions from the outside world. These nerve cells together make up a nervous system.

Nerve cells. *A nerve cell, or neuron, is like any other cell in being made up of protoplasm and in containing a nucleus. It differs, however, in being very irregular in shape, with many short branches (called *dendrites*) and usually one long branch (called an *axon*).



A nerve cell, or neuron. What was said in an earlier chapter about the size of neurons?

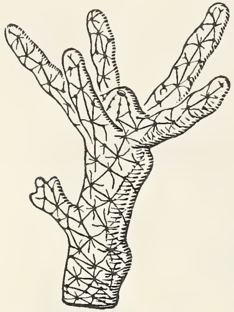
Neurons are of three types: sensory neurons, motor neurons, and associative neurons. A sensory neuron is one which receives an impression, or stimulus, and carries it toward the brain. A motor neuron is one which carries an impulse from the brain or the spinal cord to a gland or a muscle. An associative neuron serves to connect sensory and motor neurons.

Usually two or more nerve cells are necessary for a reaction. The ends of the sensory nerve receive the stimulus at the surface of the body. The impulse then travels to the other end of the sensory nerve cell. Here it passes to an associative nerve cell, which carries it to a motor nerve cell. The impulse continues along this motor nerve to the end which is attached to a muscle. Thus the stimulus received by a sensory nerve results in a reaction of a muscle some distance from the point where the impulse was received.

Sometimes the impulse may pass from the first nerve end to several others, and may thus at the same instant reach several motor nerves connected with different muscles. For example, if you touch an ant or a beetle, it immediately tries to escape by crawling faster. The stimulus is carried by a sensory nerve from the spot where you touched the insect to one or more associative nerves and by them to a number of motor cells connected to many muscles.

In nearly all animals, neurons are grouped together in definite parts of the body. Large groups of neurons compose the brain and the spinal cord.

Numerous smaller groups make up bodies called ganglia (singular, ganglion). Certain nerves which connect parts of the body that are some distance apart are very long. A nerve, or nerve fiber, consists of several separate neurons, all bound together by protecting tissues.



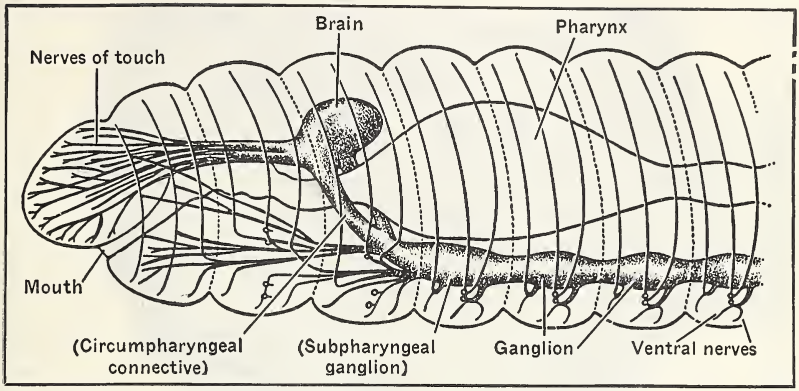
The nerve net of a hydra. Can you explain how it is possible for the whole body of a hydra to contract when one tentacle is touched?

The nervous systems of simpler animals. In general, the more primitive the animal, the more primitive is its nervous system. Thus the sponge has no true nerves. Some of its body cells, however, are modified to receive stimuli and to carry impulses to the parts of its body near the point where the stimulus is received. *Hydra,* a somewhat more complex animal, has true nerve cells, or neurons, in both outer and inner layers. These are joined throughout the body to form a nerve net. The starfish represents a further advance. It has neurons grouped in definite parts of its body rather than scattered throughout. Most of the nerve tissue is in a ring around the mouth. The earthworm has a higher development, a simple brain made up of a mass of neurons at one end of the body. It has other smaller masses of nerve cells, called ganglia, in each segment.

Reflexes and instincts. If one tentacle of a hydra is touched, the entire animal will contract into a ball. The stimulus which was applied at one point was carried all over the animal by the nerve net. Such a reaction as this movement of one part of an animal in response to a stimulus applied to another part is called a *reflex action,* or *reflex.*

The reactions of the starfish are tropisms and reflexes, similar to those of still lower forms of life. An example of its tropisms is its reaction to light. During the daytime it usually hides on the under-surface of a rock or in some other dim or dark place and travels about at night. An example of its simple reflexes is its effort to keep right side up. If a starfish is put on its "back," with its tube feet up, it bends its arms and by pushing against a rock turns over.

Most of the earthworm's reactions to stimuli are simple tropisms and reflexes like those of simpler organisms. But the worm is capable of a more complex type of nervous reaction. This is illustrated by its method of making a burrow in the ground. All the earthworms that we know about make their burrows in almost exactly the same way. Of course they were not taught by their parents how to make a burrow, nor did they ever see one made.



The nervous system of the earthworm. In what respects does this nervous system mark an advance over that of *Hydra*?

The making of a burrow is a fairly complex process. It is made possible by a fairly complex nervous system. This inherited equipment of nerves enables earthworms to make their burrows in a certain way which never varies much. The behavior which results from a tendency to react in a complex unlearned way is called an *instinct*.

Experiment 57. To what stimuli other than those described in the preceding paragraphs does an earthworm seem sensitive? Place a live earthworm on moist sand or dirt in a box. What does it do? What stimuli do you think make it act so? When the worm is quiet, tap sharply on the side of the box. What does the worm do? Touch various parts of its body with your pencil. Are all parts equally sensitive to touch?

Self-test. **1.** The simplest animals have *simple* nerves.

2. The *more* simple the nervous system, the *less* simple the possible reactions it can have.

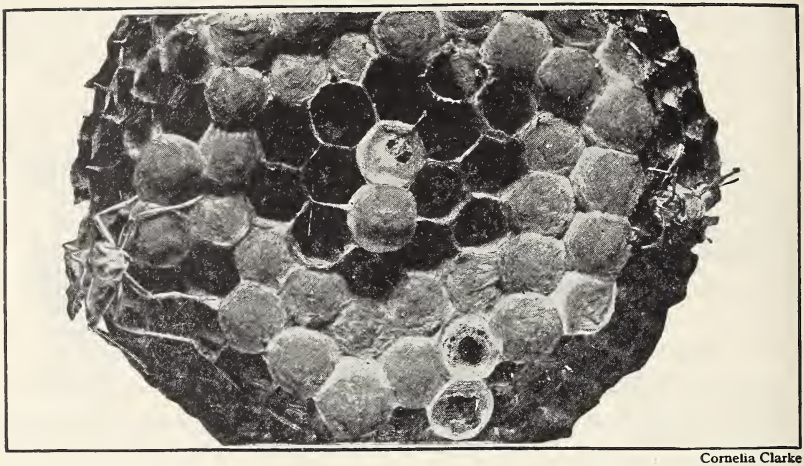
3. In general, the higher the animal, the less *complex* is its nervous system.

4. Stimuli are carried to the brain, and from the brain to muscles, by means of --?--.

5. A *motor* nerve may connect with several *sensory* nerves.

6. Scratching a mosquito bite is an example of (1) a tropism; (2) a reflex; (3) an instinct; (4) a learned reaction; (5) continued learning.

7. The building of a dam by a beaver is an example of --?--.



Cornelia Clarke

Nest of *Polistes* wasp. Does the wasp learn how to make its nest? Explain

WHAT RESPONSES CAN INSECTS MAKE?

The nervous system of an insect. If you have ever tried to capture a grasshopper or a fly, you know it very readily becomes sensitive to your approach and is able to react quickly.

The nervous system of an insect is not so very different in appearance from that of an earthworm. The organization of this nervous system, however, is more complex and more efficient, partly because of the numerous sense organs.

The brain of an insect is in its head. Most of the organs of special senses, moreover, are located on the head. This arrangement marks a distinct advance over the nerve equipments of simpler animals, since it enables an animal which moves head foremost to learn most readily what it is about to encounter. Because of its more highly organized nervous system, an insect is more fully aware of its environment and can react to it in more different ways than simpler animals.

The reactions of insects. Many of the actions of insects are tropisms. For example, if all but one window of a room are darkened, the flies in the room will collect at that window. If an insect like a ladybug is picked up on a stick, it will crawl to the top of the stick. If the stick is then turned around, the insect will again crawl toward the top.

Other sorts of behavior which we observe in insects are reflexes. For example, a fly moves quickly when a person moves to strike it. More complex responses of an insect may be termed instincts. A honeybee makes comb like that made by all other bees of the same species. The newly hatched silkworm larva will hunt out the mulberry leaves on which it feeds and will refuse most other kinds of leaves. A fly will instinctively lay its eggs on decaying organic matter, which will serve as food for its young.

An ichneumon fly. "This insect . . . is drilling into hard maple wood to lay an egg in the burrow of a wood-boring larva. How long she had been there before I found her it is impossible to state, but for more than two hours she worked, inserting and partially withdrawing her drill repeatedly until it had penetrated nearly two inches into the hard wood. At last she withdrew the drill, apparently satisfied, and flew away, to save more maple trees from borers, I hope."[1] How do you explain the ichneumon fly's behavior?

Often the instinctive actions of insects seem so complex that it is difficult to think of them as being purely mechanical reactions, as they are. The actions of a certain larva which is a parasite of one of the wild solitary bees illustrate this statement. Following their inherited instincts these tiny larvae lie in wait for this certain kind of bee at the mouth of the underground tunnel in which she builds her nest. As she approaches, several of the larvae leap upon her back and bury themselves in her hair. Here they remain motionless while the bee, following her instincts, makes the necessary journeys to the flowers for materials with which to construct her cells and to store them with food for her young. But the instant she lays an egg in a cell, the egg somehow serves as a stimulus to the little parasites. Immediately they leap upon it, for it is the bee's egg which they use for food. The bee seals the cell in her customary mechanical way—the only way which her inherited nerve structure permits. She has no way of knowing that her egg will be eaten, nor can she alter her behavior in the slightest degree.

Another example of the instinctive behavior of insects may seem even more remarkable. An investigator placed in several saucers various kinds of sweet substances upon which he thought the honeybees might feed. Soon a passing bee stopped to investigate. It seemed to like best a dish of honey and water. Finally it flew away, back to the hive. Before long it returned, followed shortly by other bees, until many of the insects were engaged in transferring the honey to the comb. Evidently the bees had somehow been able to learn of the discovery made by the first bee. How they did this the investigator was not able to discover. At last the supply of honey was exhausted. The bees stopped coming almost as suddenly as they had appeared. Somehow they had discovered, without each one's investigating, that all the food was gone.

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[1] From Clifton H. Hodge's *Nature Study and Life*, Ginn and Company, 1902.

A fish-hawk's nest on a telephone pole. What modification of an instinct is shown here?

We must not interpret these actions as thinking or remembering in the same sense that man thinks and remembers. The actions of the bees were purely mechanical and in response to stimuli which the observer was unable to detect.

Summary comparison of tropisms, reflexes, and instincts. *Tropisms, reflexes, and instincts are alike in being inherited and unlearned. A tropism, however, is in general somewhat simpler than a reflex, and a reflex is in general somewhat simpler than an instinct. Furthermore, a tropism is somewhat more definitely fixed and automatic than a reflex, and a reflex is more definitely fixed and automatic than an instinct. In other words, higher types of response are in general more easily modified than lower types. For example, birds inherit the instinct to build nests. Each species builds its nests in the same general form, in the same sort of location, and in general of the same sorts of materials. But if a bird cannot find the customary location or materials, it will use the best substitute it can find. In one unusual case a robin built her nest and raised her young on a traveling crane in a ship-yard. Returning with food for her brood, she flew to the crane in whatever part of the yard it happened to be, paying no heed to the uproar and confusion about her.

While it is true that instincts, such as nest-building, can be modified considerably, it must not be concluded that only instincts can be modified. In the next chapter it will be shown that with many animals reflexes and even in some cases tropisms can be modified somewhat by experience.

Tropisms, reflexes, and instincts must not be confused with such bodily actions as those of digestion, heart-beat, breathing, and elimination. These also are automatic and involuntary. They continue during the life of the organism, no matter what its activities or environment may be. They can be modified for a time, as when a person holds his breath, but such modification is only temporary. On the other hand, when a reflex or an instinct is modified, the modification is usually permanent.

Self-test. 1. Unlike the lower organisms, the insects have most of their sense organs on their *legs.*

2. *Most* reactions of insects are unlearned, automatic, and not easily modified.

3. The care given to certain plant lice ("ant cows") by ants is an example of a *reflex.*

4. The biting movements of the jaws of an ant when it is seized furnish an example of a *tropism.*

5. The crawling of an ant away from the vicinity of a fire is an example of a *reflex.*

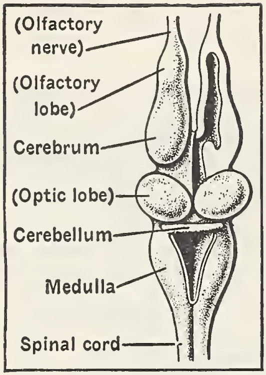
WHAT RESPONSES CAN CHORDATES MAKE?

The nervous system of a chordate. The development of an internal skeleton makes possible a complex and delicate nervous system. The spinal cord of the vertebrate is enclosed and protected by the vertebrae. It does not lie along the lower side of the body cavity, as the nerve cord does in insects and other invertebrates. The brain is enclosed and protected in the skull.

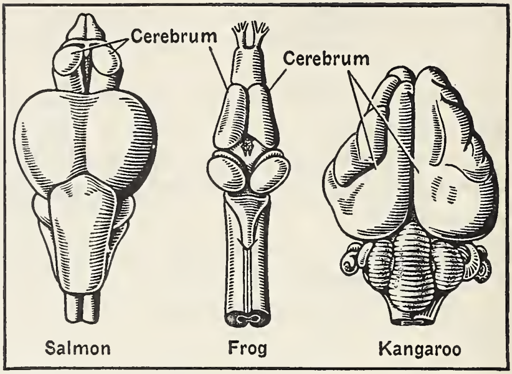
In the preceding sections it was shown that as low in the scale of life as the earthworm, there is the beginning of a brain, though such a brain is merely the largest of several ganglia. The brain of the insect, which is the highest of the invertebrates, is a complex structure of two lobes having many nerve connections with special sense organs and with the various parts of the body. Yet the insect brain is relatively simple compared with that of the lowest vertebrates.

The nervous system of the frog. The frog has a brain composed of several parts. The most important parts are the olfactory lobes, the cerebrum, the optic lobes, the cerebellum, and the medulla (medulla oblongata). The olfactory lobes carry sense impressions from the nose. The function of the cerebrum of the frog is not yet certainly known. In the higher animals the cerebrum controls the voluntary actions. Voluntary actions are those that are controlled by the will. The optic lobes of the frog have some control of its reflex actions. They also control vision. The function of the frog's cerebellum has not yet been determined. The medulla of the frog, which is merely a broadening of the spinal cord, controls most of the essential life processes. These processes include breathing, eating, heart-beat, and the simple reflexes in general, such as swimming and jumping.

The frog is capable of some of the same kinds of nervous reactions as are the simpler organisms. It has tropisms. An example is its reaction to light,



Frog's brain. Self-test on Mastery of Facts: For how many of the structures named here can you suggest functions?



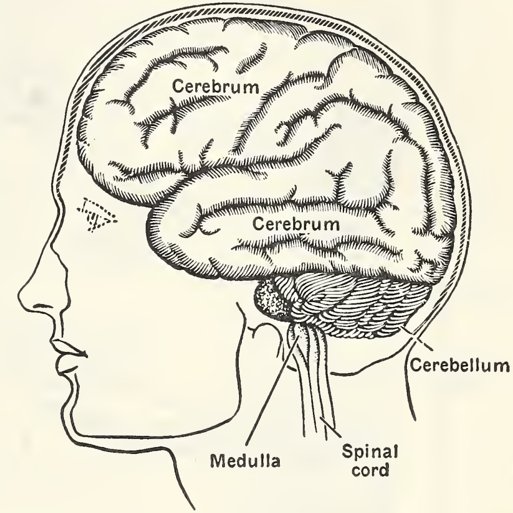
Brains of typical chordates. Should you expect the cerebrum of the human brain to be larger or smaller in relation to the rest of the brain than that of some or any of these brains? Justify your answer

to which both its eyes and its skin are sensitive. It has many reflexes or instinctive acts, such as swimming and jumping or diving when touched or when it hears a sudden sound. Most of its reactions are unlearned behaviors, such as the invertebrates show. Yet because it possesses a true brain, with a small but definite cerebrum, it is capable of making many more responses to a stimulus than can the simpler animals. A reason is that there are more cells in the brain and hence more possible connections between sensory nerves and motor nerves. Thus, if a frog were sitting on a lily pad when a bird came near, the sensory nerves of the eyes would send to the brain information concerning this possible danger. The frog could react in several ways, depending on what set of muscles received the command to move. It might lie flat on the leaf to escape being seen. It might slide quietly off the leaf into the water. It might jump.

The nervous system of man. When we study the vertebrates, we find an increasing size of brain as we progress up the scale of life. The more intelligent the animal, in general, the greater the size of the cerebrum in comparison with the other parts of the brain.

*The central nervous system of higher animals is composed of a brain, a spinal cord, and the nerves branching from them. Ten to twelve pairs of nerves (the peripheral nerves), each composed of many fibers, branch to various parts of the body from the brain. Other similar pairs of nerves pass out between the vertebrae from the spinal cord to all parts of the body. A chain of ganglia extends on each side of the spinal cord and connects at various points with the brain and the spinal cord. These make up the sympathetic nervous system, which will be discussed later.

The functions of different parts of the nervous system are known in only a general way. Exactly how any of these functions is carried out is not yet known. The cerebrum controls voluntary actions and our remembering and thinking. It is also the seat of the special senses. The cerebellum controls the actions of the muscles, so that they work together. For example, there are dozens of muscles used in walking. If they did not all work together properly, one could not walk. The medulla controls such involuntary movements as those connected with the beating of the heart and breathing. Through it pass many nerves to the spinal cord.

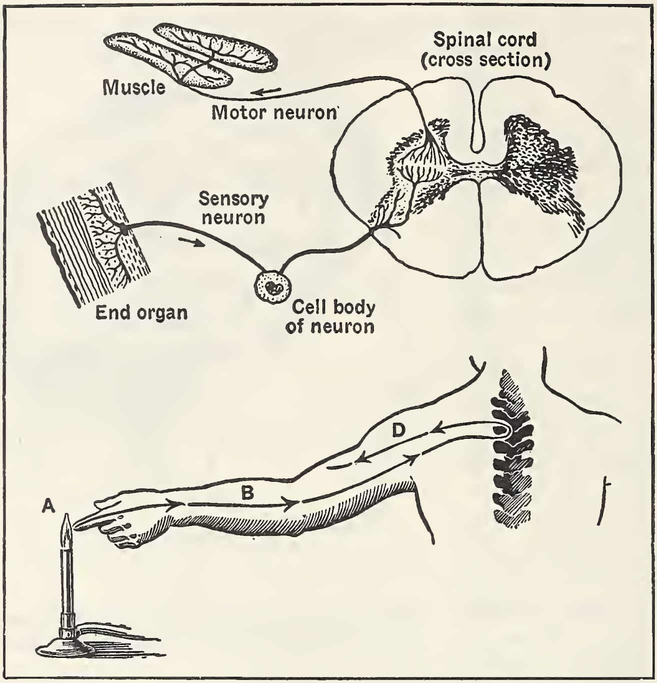


Brain of man. State the chief functions of each of the parts of the nervous system labeled here

The spinal cord extends from the base of the brain almost to the end of the backbone. It serves (1) to convey nervous impulses between the brain and all parts of the body, and (2) to control many of the reflexes, such as dodging, leaping from danger, coughing, and the like.

The fact that simple reflexes can be carried on through the spinal cord without the help of the brain has great survival value. Although impulses pass along nerves at the rate of from about half a foot to three hundred feet per second, nevertheless *some* time is required for a nerve impulse to pass up the spinal cord to the cerebrum and back to the motor nerves. When the reflex is controlled by the spinal cord, this time is saved. Thus it might be impossible to leap to safety from an approaching automobile if one had to wait to think about how and where to jump.

Man inherits reflexes and instincts, just as other animals do. That is, the responses he will ordinarily make to some stimuli are already determined



A reflex arc. Explain how a reflex action is performed. Why does one jerk his hand away from a flame even before he feels pain?

by the close connection between the sensory nerves receiving the stimulus and the motor nerves governing the response to it. Thus, if a baby starts to fall, it will clutch at something for support. So strong is this clutching impulse that a newborn baby can hold to something and support its entire weight. One instinctively fears sudden loud noises, though one may learn to modify this instinctive fear.

Many essential activities go on in our bodies without any voluntary control. Examples of such activities are those concerned with the circulation of the blood, the digestion of food, the work of glands, excretion, and many other functions. These movements are controlled by the sympathetic nervous system working in harmony with the medulla and the cerebrum.

Alcohol, tobacco, and the nervous system. Alcohol acts directly upon the nervous system. It affects the coverings of the neurons and thus interferes with their normal functioning. Generally, drinking alcoholic liquors at first causes nervous excitement. If the drinking is continued, this excitement changes to a stupor or even to unconsciousness. A person under the influence of alcohol is to a greater or smaller extent deprived of his ability to perform the highest intellectual tasks effectively. He is also unable to control his nerves and muscles effectively in performing tasks demanding speed and accuracy. Therefore even moderate drinking has been found sufficient to prevent athletes from making their best performances. Furthermore, moderate drinking is often the cause of serious automobile accidents.

In a similar way the use of tobacco has been found to be associated with reduction of efficiency of high-school students in athletics and in scholarship.

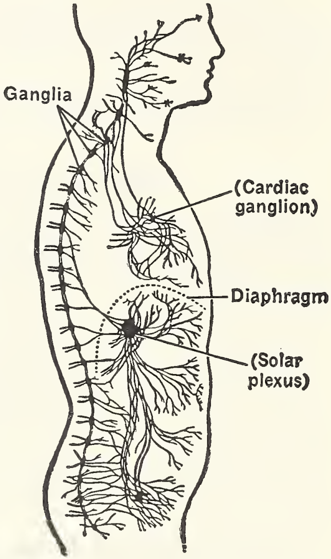


Diagram of sympathetic nervous system. With what activities is the sympathetic nervous system concerned?

Self-test. 1. *Most* vertebrates have brains.

2. A fish, such as the trout, has a *less complex* brain than an ant.

3. The central nervous system of man is composed of a --?--, --?--, and --?--.

4. The *medulla* of a higher animal controls such reactions as deciding to fight, to run, and to hide.

5. The *cerebrum* of a man is larger compared with the rest of his nervous system than the *cerebrum* of an elephant or a whale.

6. Such actions as the use of both hands in lifting an object are believed to be controlled by the *cerebrum.*

7. Such involuntary movements as blinking the eye are controlled by the *cerebrum.*

8. Man's chances for survival would be *increased* if his reflexes were controlled by the cerebrum instead of by the *cerebellum,* as is now the case.

9. Alcohol and tobacco are of *small benefit* to the nervous system.

Self-test on Important Biological Terms

cerebellum
cerebrum
ganglion
instinct
medulla
nerve
neuron
reaction
reflex
response
sense organ
stimulus
tropism
unlearned reaction

Self-test on Biological Principles. 1. Can you explain this statement: "Unlearned responses differ in degree rather than in kind"?

2. What evidence can you give from this chapter which supports the principle "Increased complexity of structure is accompanied by an increased division of labor"?

3. Can you find the statement of a principle in the "Summary comparison of tropisms, reflexes, and instincts," on page 424?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Dealers in plants sometimes tell us that our house plants will grow much more vigorously if we water them by standing the flowerpots in water rather than by pouring water on from above. Can you explain why this statement is usually true?

2. Summarize the ways in which tropisms are of value to a plant.

3. A baby beaver raised as a pet in a city home far from its native habitat tried to build a dam across the living-room floor, using various objects which it had collected about the house. How would you explain this behavior?

4. Why is a blow at the base of the skull more likely to cause death than one on the top of the skull?

Exercise on Scientific Method. Inventing Experiments. Can you invent an experiment to find what members of your class can control their fears of sudden noises?

Special Reports. 1. What is a compass plant? Why is it so called? (Consult an advanced botany textbook or an encyclopedia.)

2. Look up in an advanced biology or zoology textbook the story of the relations of the *Pronuba* moth and the yucca. Does the moth act intelligently? Explain.

3. Look up in one of the many insect books by the great French naturalist Fabre some accounts of instinctive action.

4. Carrier pigeons were used to some extent for carrying messages during the Second World War. How is this practical use made of the homing instinct of the pigeons?

CHAPTER XXII

Learned Responses

Questions This Chapter Answers. 1. How is learning related to experience? · 2. What are the factors of learning? · 3. What is meant by memory? · 4. How are habits formed? · 5. Can older people continue to learn? · 6. Is it true that if one is able to do certain things well, one probably will be unable to do other things well? · 7. What are some of the advantages of a long period of infancy?

WHAT ARE SOME FACTORS IN ANIMAL LEARNING?

Learning by experience. Two meadow larks taken from the nest when very young and brought up by hand had to learn to eat when they had developed sufficiently so that they no longer needed to have food put into their mouths. At the sight of an earthworm placed on the ground in front of them, they immediately began pecking with their bodies stiff. Sometimes they hit the worm with their beaks, but often at first they did not. They improved rapidly, however, and before long could pick up and eat a worm or an insect as expertly as could an adult bird.

Learning of this type may be explained thus: The young birds when hatched were equipped with nerves which enabled them to make the pecking motions when they saw the food. But they needed practice in perfecting the movements. At first the impulse might go to muscles which did not produce the desired response, that of seizing the worm. These movements did not give satisfaction. Those which resulted in seizing the worm did. Little by little the useless and therefore unsatisfactory movements were eliminated. There remained only the response which brought satisfaction in securing the worm.

This type of learning, which makes some instinctive action perfect through practice, is found in all animals that have complex instinctive nerve patterns. Thus the human baby may reach for an orange on the table, but he must learn through experience when the orange is near enough to be grasped. Such learning, however, is not true learning in the sense that the animal acquired some response totally new and different from any which it would ordinarily make. Also, when the human baby is first learning to feed itself, it may sometimes put the spoonful of food into its ear or its eye instead of into its mouth. Furthermore, it is certain to spill much of the food. It is certain, too, to "miss its mouth" with the spoon often before it learns through experience and practice to steer the food safely into its mouth every time it tries.

Learning by modifying responses. The important difference between an unlearned response and one that is learned is that the learned response is

Parfitt

Is learning going on here? Explain

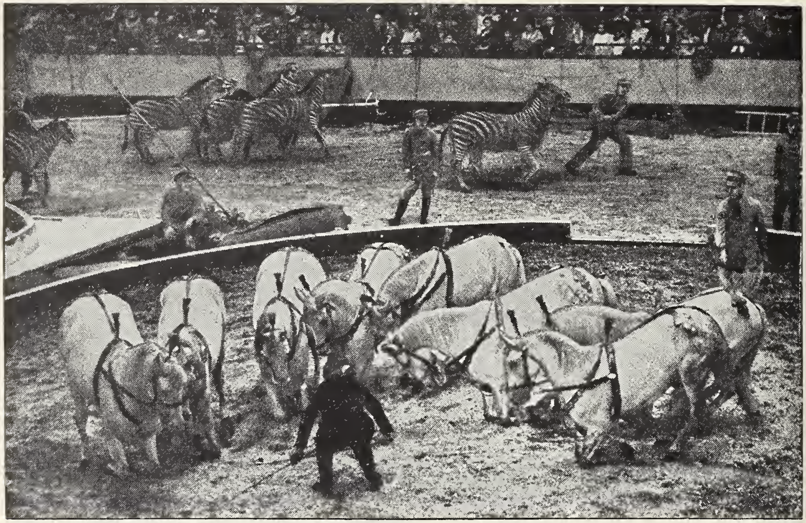
gained through experience. Learning, therefore, consists in modifying responses. Some sort of true learning is possible with animals very low in the scale of life. Scientists report that even amoebae and paramecia have been observed to modify their usual responses in such a way as to indicate possible learning. For example, two investigators directed a beam of light upon the water just in front of an amoeba. It will be remembered that *Amoeba* avoids light. When the amoeba reached the light beam, it reversed its movement, then moved forward again. Again it reached the light beam and withdrew. After it had encountered the beam several times, it changed its direction and avoided the beam entirely. This experiment was carried on with five amoebae and was repeated with them a number of times at intervals of about three minutes. In later trials three of the amoebae made fewer forward movements before changing direction than they had first made. It is not understood how an animal like an amoeba, which consists of only one cell, can modify its responses in this way.

Learning and inherited reactions. Learning begins with the inherited reactions. Since learning consists in modifying responses, the simplest learning must consist in modifying the inherited responses, that is, tropisms, reflexes, and instincts. The "learning" by the amoebas which has just been described is an example of a modified tropism. More striking examples of learning of a similar type have been observed with some of the simpler Metazoa, for example, starfish. Jennings trained a number of these animals each to use a certain arm in turning itself over when placed on its "back." One of the starfish learned this lesson after one hundred eighty trials distributed over a period of eighteen days. More astonishing still is the fact that a week later it used the same arm to turn itself over. Somehow it retained, or "remembered," what it had learned.

The simple action of turning over is a reflex, just as is the contracting of a hydra when its tentacles are touched. But using one certain arm in turning over is clearly different from the inherited reflex. The ordinary reflex had been modified by training.

A "seeing-eye" dog leading his blind master across a busy street. What are the social implications of this picture?

A few examples of modified tropisms and reflexes of Metazoa even simpler than the starfish have been reported. Examples of modified reflexes and instincts are common with animals higher in the scale of life. One investigator trained crayfish to come to him for food. Another taught May-fly larvae to come for food in the bright sunshine, although these animals instinctively avoid light. One of these May-fly larvae, much "brighter" than the others, learned after two months of training to come quickly to the upper side of a rock and to go to its feeding place when the rock was slightly jarred. Cockroaches were trained to distinguish between left and right. The fish in a pond were trained to come to a certain spot for food whenever two small stones were struck together in the water at the edge of the pond. A carp, after being lifted out of the water on a barbless hook a number of times, learned not to eat worms which were on a fishhook. It learned also to distinguish between worms on a hook and worms which were not. Thus, although a carp ordinarily draws in water when it approaches its food, this "trained" carp learned to do just the opposite. On approaching a worm it sent a current of water toward the worm. If the worm was not on a hook, the current lifted



Keystone

Why are horses capable of learning more tricks than are fleas?

it somewhat, whereupon the carp ate it. But if the worm was on a hook, the current did not lift it, whereupon the carp made no effort to suck it in.

Dogs, rats, elephants, monkeys, and other mammals are able to change their inherited responses more than animals lower in the scale of life because their nervous systems are more complex.

Choice of response. Learning involves a choice of response. When an organism reacts to an ordinary situation with its customary tropism, reflex, or instinct, it does not learn. No matter how often it might repeat such an action, it would not learn, because there is no choice of action. There is no stimulus to act in any but the usual way. If, however, some new condition is introduced, it then becomes necessary for the animal to choose which action it will take. To illustrate, the amoeba crawling into the beam of light had two choices. It could continue in the unpleasant light, or it could go in some other direction where the unpleasant condition might not be encountered. The starfish placed on its back with all but one of its arms fastened down had two choices. It could lie still in spite of the stimulus to turn over, or it could turn over by using its one free arm. The crayfish seeing food held out to it had also two choices. Either it could follow its instinctive tendency to avoid a big moving object, even though by so doing it remained hungry, or it could approach the threatening object and get the food.

VACATION-TIME BIOLOGY

Sue found the little painted turtle on our front lawn. It was evidently migrating, for it was traveling about as fast as it could. That it had come safely two miles from the river seemed impossible; yet there it was. We put it in the back-yard pool, for it must soon fall a victim to an automobile if left to wander about.

The turtle seemed contented enough in the pool. It had plenty of room to swim about, abundant hiding places under water, and many lily pads on which to rest while sunning itself.

We fed it bits of meat. It seemed to associate big moving objects, such as people, with its food; for it began to appear whenever anybody approached the pool.

"I believe I could teach that turtle to eat out of my hand," said Ned.

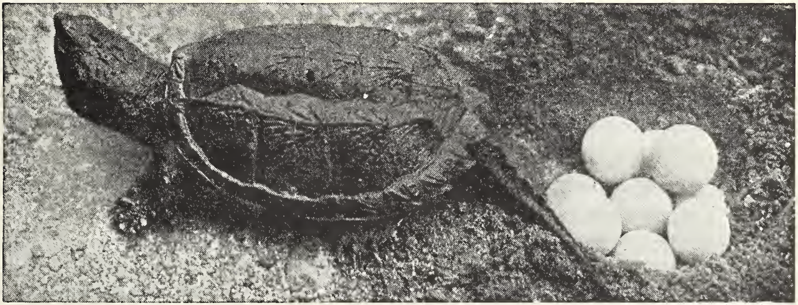
"Surely not," said Sue. "Turtles aren't intelligent enough for that, are they?"

"I don't know, but we'll find out."

Ned extended his fingers with a small piece of meat between them as far toward the turtle as he could, and held them motionless just above the water. Slowly the turtle approached. After many stops to look for possible danger, it seized the meat. It then dived and swam rapidly away, with the meat in its mouth.

"There," said Ned. "I think in a few days he'll stay by my hand and eat." Two days later it climbed into Ned's hand for food.

As the vacation drew toward its close, we faced the problem of what to do with the turtle during the winter. It was too large for the goldfish bowl in the house, and we knew it would freeze to death if left in the pool; for the pool would freeze solid, and there was no mud in the bottom in which the turtle might burrow for protection against the cold. Finally we decided to put our pet back into the river. This we reluctantly did on the day before school opened.



Lynwood M. Chace

The snapping turtle was photographed just before it covered its newly laid eggs and then returned to the water. Some people say that building this sort of nest is an instinctive reaction. Are they right? Explain

Mrs. Joseph Watson

Unique learned response. Can you suggest a method which might have been used in teaching the animals to perform this trick?

With the simpler animals choice is, of course, automatic and immediate. The animal does not consider or plan what it will do, as a man would. It reacts in the way which is easier or more satisfying at the moment.

Pleasure and annoyance.[1] Learning depends largely on pleasure and annoyance. When an animal meets an unusual condition in its environment, it tends to react in accordance with some inherited tropism, reflex, or instinct. But if there is present some other condition, which pleases or annoys the animal, the animal may modify its ordinary response. It may need to perform many actions before it happens by chance to hit upon the one which brings satisfaction either by securing the pleasure or reward or by avoiding or getting rid of the annoyance. Whenever the animal again meets the same situation, the tendency is to repeat the actions which before resulted in satisfaction and to eliminate those which brought annoyance or did not yield satisfaction. To illustrate these statements: The amoeba crawling into a beam of light immediately reversed its direction. It again went forward and upon striking the light again retreated. It repeated the action until finally it succeeded in avoiding the unpleasant condition. The starfish placed on its back was uncomfortable. It probably tried to use various arms before it chanced to use its one free arm and thus finally succeeded in turning over. The crayfish when offered food found annoyance caused by hunger stronger than annoyance caused by fear. In each of these and the other cases which have been cited,

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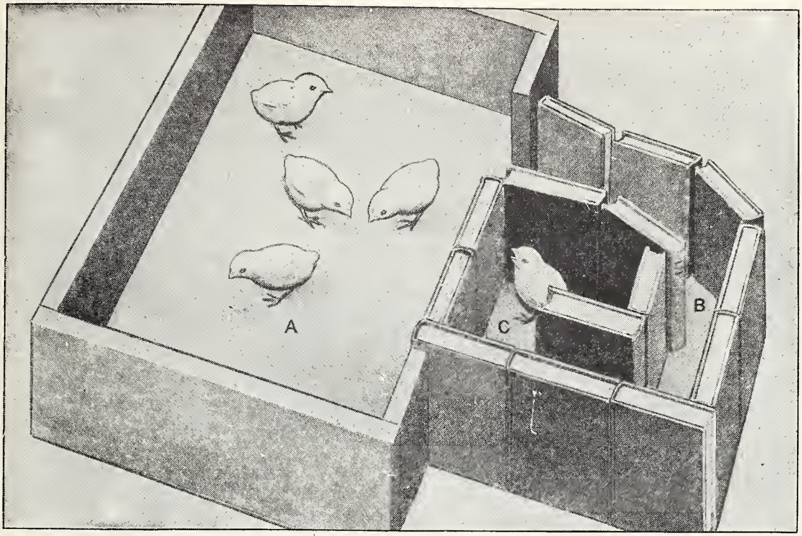
[1] ***Annoyance*** **(ă noi′ăns): that which displeases or annoys.**



An experiment in animal learning. How did this learning depend both on trial and error and on pleasure and annoyance?[1]

the animal secured satisfaction by performing an unusual action. The result of this satisfaction was that the animal repeated the action under the same circumstances later.

Trial and error. It is clear that in its simplest forms animal learning is merely the result of trial and error. The stimulus furnished the animal which is being trained is usually either something pleasant, like food, or something unpleasant, like receiving an electric shock or being left alone. At first the animal probably makes several different reactions to the stimulus. Finally, purely by chance, it does something which results in securing the pleasant condition and avoiding the unpleasant one. When next the animal meets the same condition or stimulus, it tends to repeat the action that before gave it satisfaction. But it probably again makes a number of reactions before by chance it again hits upon the right one. With each later attempt it reduces the amount of trial and error necessary to make the desired response. Thus the animal finally changes its original reactions and learns to react in a certain unnatural way.

How animals learn by modifying their responses through trial and error is well illustrated by the actions of animals in learning to find their way through

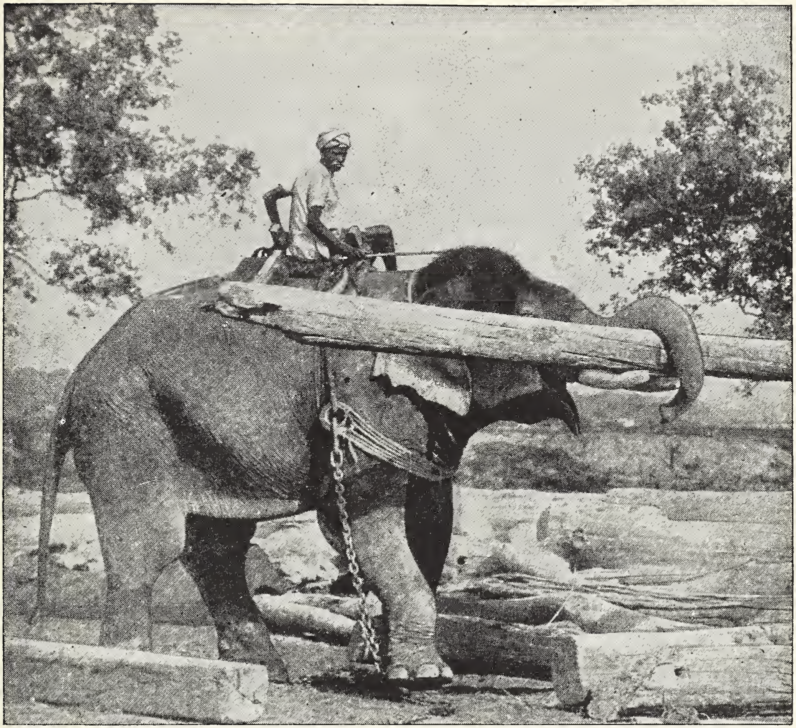
[1] After Thorndike's *Educational Psychology.*

a labyrinth, or maze. An investigator describes such an experiment with two chicks six to twelve days old. Using books for walls he constructed a simple maze connecting with the chicken pen. He then placed each of the chicks in turn in the space where the single chick is shown in the figure. The chick reacted with aimless movements repeated many times, such as running about making loud cries and jumping at the walls. Finally it happened to find the way out of *C* and in the same way discovered, one by one, the various turns of the maze. After several aimless movements at each turn it found its way into the main pen with the rest of the chicks, where it was content to remain. When it was again put into the maze, it behaved much as before but took a somewhat shorter time to escape. With later trials it made fewer and fewer useless and aimless movements. Finally each chick learned to escape from *C* into the main pen within five or six seconds.

By a similar process of eliminating useless movements by trial and error a land snail learned a maze which had only one turning. Ants learned a maze with several turnings. Fish learned very simple mazes. A green frog took a hundred trials to learn a maze with only two choices, and a toad was about equally slow to learn. Turtles, however, learned a maze with four blind passages and two sloping boards. One of these boards the turtles had to learn to ascend and the other to descend. The maze was further made complex by requiring the turtles to turn as soon as they reached the bottom of the descending board. They soon learned to begin to turn before they reached the bottom, and finally to drop over the edge of the board as soon as they reached the top.

Habit formation. Learning frequently results in forming a habit, if an animal repeats a reaction many times. The tricks which dogs, cats, monkeys, and other animals learn are modified inherited responses. Through repeated trial and error, accompanied by rewards for the desired responses or punishments for the undesired ones, the animal acquires the habit of reacting in a certain way in a certain situation.

Occasionally there are reports of remarkably intelligent dogs or horses which apparently think and reason like people. A gifted Arabian horse, Muhammed of Elberfeld, Germany, was reported to have learned to add and subtract in two weeks; to have passed from multiplication and division to the use of fractions in three more days; and later to have learned to solve problems in square root and cube root. Rolf, the Mannheim dog, was reported to be able to do similar things. But careful scientific observations of these animals convinced scientists that the animals were not really able to solve the problems they seemed to solve. It was not discovered just what were the stimuli which caused the animals to tap out with their feet the correct answers. Nevertheless there were a number of reasons which convinced the experimenters that these



An elephant can be taught to place these heavy teak logs in neat piles. After he has established the necessary nerve connections, he will pile logs all day steadily and carefully, and needs nobody to direct him or to see that he keeps working. Many men under the same conditions would neglect the work or would not make neat piles if there were nobody to watch them. How do you account for the fact that in this case the elephant is more "trustworthy" than man?

responses were after all only instinctive reactions modified through trial and error into habits, and that the animals reacted to signals given by somebody present.

Self-test on Understandings. Can you explain and give an example (original if possible) of each of the following seven statements?

Learning results from experience.
Learning consists in modifying responses.
Learning begins with inherited reactions.
Learning involves choice of response.

Learning depends largely on pleasure and annoyance.
Simple learning is a trial-and-error process.
Learning frequently results in forming habits.

Self-test. 1. *Unlearned* responses are gained only through experience.

2. *None* of the animals in the lower phyla *is* able to profit by experience.

3. It is possible to modify *two* of the three types of inherited response.

4. A starfish placed on its back and allowed to turn over by using any of its arms learns *little.*

5. When an animal repeats an action in the same way a number of times a --?-- is formed.

6. The simplest animals do *little* planning, but merely try one response after another until they happen upon the one which satisfies the stimulus.

7. In general, one would expect a fish to acquire a habit *less* quickly than a crayfish.

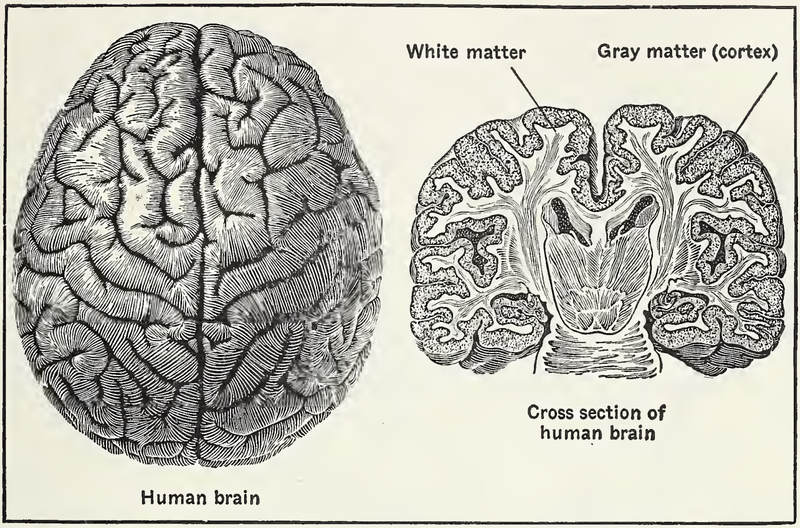
8. *Some* mammals other than man are believed by scientists to be able to solve difficult problems in arithmetic.

WHAT ARE SOME CHARACTERISTICS OF HIGHER LEARNING?

Higher learning. Some animals seem capable of reactions which require more "intelligence" than do modified reflexes and instincts. Some of the higher monkeys seem able to use memory ideas of a high order. For instance, one investigator threw a piece of apple, and, while a tame monkey was picking it up, he threw three other pieces in different directions. After eating the first piece, the monkey secured the second and sat down to eat it. When he had finished it, he went for the third piece. This he ate likewise. He then paused to watch a flying bird and to scratch himself before starting after the fourth piece. This he found where it had rolled under a board. After he had eaten this, he sat down, and did not hunt for more pieces.

Human learning. The brain of man is much more complex than that of any of the other animals. Man's cerebrum is twice as large as that of the highest monkeys. Yet, within the human race, the size of the cerebrum does not determine intelligence. The largest brain on record was that of an idiot. Many unusually able men have had smaller brains than the average person.

The cerebrum is made up of two lobes, or hemispheres, each composed of approximately eleven billion neurons. The outer surface of the cerebrum consists of gray matter. Gray matter is composed chiefly of the cell bodies of neurons. The interior of the cerebrum is white matter. This consists of bands and bundles of nerve fibers. These fibers connect the various areas of the brain



At left, human brain, seen from the top, showing both hemispheres; at right, section through cerebrum, showing gray matter of cortex and white matter. What is the advantage of having convolutions, or folds?

with the other parts of the nervous system. The vast number of nerve cells which make up the human brain make possible thinking, planning, remembering, reasoning, and the other higher thought processes. These higher thought processes distinguish man from all the other animals.

The higher centers of the brain may be compared "to the captain of a steamer who issues orders to the man running the engine when to start and when to stop, and who has his hand on the wheel so as to guide the course of the vessel."

Habit-forming in man. *Man, like many of the other animals, forms habits without thought by repeating certain actions in the same way until the nerve patterns are fixed. But man is capable of learning habits not only by the trial-and-error method, but also by intention. The lower animals cannot do this. If they change their reactions at all, they do so by trial-and-error learning.

The difference between the learning of animals and that of man in this respect can be illustrated by the learning of some skill, such as swimming. A puppy or a baby duck does not need to be taught to swim, but all dogs swim like other dogs and all ducks swim like other ducks. It would be very difficult

Galloway

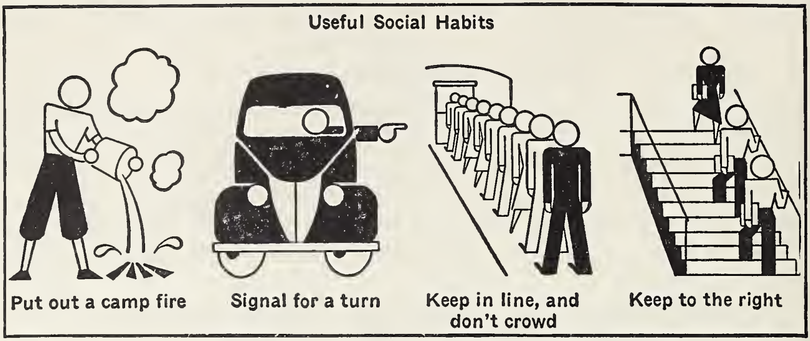
Can you state some of the steps necessary in learning to play golf?

or impossible to teach them to use any other sort of swimming stroke than the one they are able to use by instinct. A child, however, does not, like the dog or duck, swim by instinct. He must learn, and usually it is not easy for him to do so. After many trials, which usually extend over a considerable period, he learns first to keep his nose above water and to swim a short distance. He requires much more practice before he learns to swim easily.

The acquiring of such a skill as swimming is accomplished in this way: Because he has no ready-made instinctive response, the boy must learn an effective way of responding. He must therefore use the higher levels of his brain at the start. He watches other boys swimming, notices what they do, asks them how to use his arms and how to kick, and remembers what he has been told or has read about swimming. When he first attempts to swim, he has a fairly clear idea of what he wants to do. He directs with the nerves of the cerebrum every action he performs. The impulse travels from the higher brain centers along the nerves to the muscles he wants to use. He notes which movements give desired results, repeats them again and again, and at the same time consciously tries to eliminate those which his own experience and the advice he receives convince him do not give the results he wants. Finally the desired habit is formed. The stimulus of the water sets up the response without the necessity for thought any longer. The higher centers of the brain are no longer concerned. The action of swimming is entirely controlled by the lower centers.

Changing human habits. If a boy wishes to change his style of swimming to some other method, he must proceed much as before. In doing this he uses the higher centers of his brain. He carefully studies the differences between the movements he has been making and the new ones he wishes to make. He consciously changes his movements in the water, commanding the muscles with the upper brain centers. After long practice he learns to make the new response. When the new movements have become automatic, the higher brain centers are no longer needed. The activities are controlled by the lower centers. The higher centers may then be used for other purposes, such as planning new activities, carrying on a conversation, and the like, as the boy swims along.

***Rules of habit formation.** Man is the only animal possessing a sufficiently complex brain to enable him to change his habits at will. The rules for forming desirable habits and breaking up undesirable ones are definitely known and are fairly simple. Suppose you have formed the habit of taking too much time in starting to do your studying or your work at home. First, you must decide that you want to break this habit. You must analyze the actions you now perform which take too long or which prevent your getting to work at once. Thus you decide what new acts you want to perform and what old ones you want to eliminate. You then begin your work vigorously. Also, you are careful to perform the acts you have planned and to leave out all that do not help. Whenever you have such tasks to perform, you follow your new plan without any exceptions. Before long you will have formed the new habit. You will then do your work without thinking much about the way in which you do it. In other words, the higher centers of the cerebrum will no longer be concerned with carrying out the new actions. The lower brain centers will take care of the habit in a mechanical way. If, however, during the formation of the habit you permit yourself to go back to the old habit of wasting time, the new habit will require much longer to establish. If you permit too frequent exceptions to the actions necessary in establishing the new habit, you will not succeed in forming it at all.



Can you think of other desirable social habits than those shown here?

Social implications. The habits we form are not matters which concern only ourselves. Our personal habits may have great social significance. For example, one person may form the habit of always observing the established rules for travel on foot, by bicycle, or in an automobile. Thus he may have the habit of walking on the left side of the road, of riding his bicycle near the right edge of the highway, and of making a complete stop at all stop signs and red traffic lights. Another person may have the habit of paying no attention to such rules.

Group habits may have greater social importance even than individual habits. For example, the people of one neighborhood group may have the habit of always protecting their supply of fresh water and of keeping the grounds about their homes neat and free from trash. Another group may form the habit of having no concern for the rules of community welfare. Again, the students of one school may have formed the group habit of encouraging the practice of courtesy in and about the school and of being industrious in doing school work. Another group may have formed the group habit of being rude and lazy. Such a group habit as making every fire drill as perfect as possible may result in safety instead of tragedy in case a real fire occurs.

Continued learning. In the learning experiment with starfish described in an earlier part of this chapter, Jennings found that young starfish acquired the modified reflex more readily than older specimens. Animal-trainers usually use young animals rather than old ones. Children often gain skill in games and other muscular activities more readily than grown people. From observations such as these the old saying "You can't teach an old dog new tricks" has come to be widely accepted as applying to all sorts of learning.

This saying is not so true, however, as is generally believed. Like many other common old sayings, this one is based on only partly accurate observation. It is often true that older people have more difficulty than children in learning to perform such muscular activities as those involved in playing the piano or in playing tennis. The greater difficulty, however, is probably not due to its being harder for them to learn. Whether one learns to play a game expertly or to perform intellectual tasks well depends largely on how strongly one wants to succeed. "Old dogs" usually learn less easily than "young dogs" for several reasons: (1) because they have less abundant energy; (2) because they have undergone changes in bone and muscle; (3) because they have no real desire to learn a particular skill; and possibly (4) because they already have acquired habits which interfere with the new learning and which are difficult to break.

*Many experiments have shown that it is not true that children gain intellectual knowledge more rapidly than older people. The contrary may even be the case. We gain new knowledge which involves the higher nerve centers of the cerebrum, such as learning to read a new language or to use higher mathematics, most easily in the early twenties. But there is usually so slight a loss of mental vigor as one gets older that, if one remains well and normal, there is no time of life when one cannot undertake new intellectual tasks with success.

Social implications. Unfortunately the belief is widely held that, as people get older, they lose the ability to learn easily or to adapt themselves readily and effectively to new conditions. A result of this mistaken belief is that some employers have made a practice of refusing to hire men and women who have reached the age of fifty or even a younger age. The facts stated in the preceding paragraphs, however, indicate that such a practice is contrary to scientific evidence.

Individual differences. If you have observed animals, you have no doubt noticed that some seem more intelligent than others. Jennings found that some of his starfish learned to turn over with one certain arm more readily than others. In nature those animals of any kind which are more "intelligent"—that is, more able to learn quickly and effectively—are the ones most likely to grow to maturity and have offspring. Hence under natural conditions the "stupider" ones are likely to be eliminated by enemies, while the "brightest" and therefore the "fittest" are likely to survive. There are of course individual differences among people with respect to intelligence, just as there are individual differences among them with respect to height, weight, and many other factors.

Social implications. Many people think that a person who is superior in one respect is likely to be very inferior in other respects. Thus you may hear

Cato, at eighty, began the study of Greek; Tintoretto, at seventy-four, painted *Paradise*, the largest painting on canvas ever produced; Verdi, at eighty-five, composed *Ave Maria*, *Stabat Mater*, and *Te Deum*; and Oliver Wendell Holmes, at eighty-nine, was a member of the Supreme Court of the United States. What general truth is suggested by these facts?

some pupil say, "Yes, he is able to get good marks in his school work, but he can't do anything else well." Or you may hear somebody say, "Those that are the best students in school are not so likely to be successful in later life as average students." The opposite of such statements, however, is usually true. There are exceptions, of course; but it is in general true that the person who can do intellectual tasks well is likely also to be superior in other respects. Furthermore, evidence shows that the proportion of good students who are successful in later life is greater than the proportion of poor students who win later success. It should be remembered, however, that there are very few people who cannot learn to do well something which is important to themselves and others. Whether you are an excellent or only a fairly good student, you can make for yourself a pleasant and valuable place in your school and later, as an adult, in your community if you will find worthy activities which you like to do and if you will then learn to perform these activities well.

Advantages of a long infancy. The human baby is under its parent's care and instruction for a longer time than the young of any other animal. In general, the more complex the nervous system of the animal and the higher the development of its cerebrum, the longer is its period of infancy. Thus few invertebrates, even the highest ones, the insects, are cared for by their parents. Few even of the lower vertebrates, the fish, amphibians, and reptiles, have a period of infancy during which their parents provide them with food, shelter, and protection. The birds for the most part take care of their young for a short time, and the mammals for a longer time. The highest monkeys have a period of infancy which lasts sometimes for several years. Man, with the most highly developed cerebrum of all animals, has a period of infancy which lasts legally twenty-one years, or until "the young man comes of age." Different people vary so greatly, however, that some are able to care for themselves completely before that age, others not until they are much older, and a few never.

The more highly developed brain makes a period of infancy necessary for the survival of the species. The higher animals, with their complex nervous systems, must have time to make and perfect the responses necessary for their existence. The more complex the cerebrum, the greater the possibilities of varied behavior—consequently the longer the time that must be allowed the animal in which to learn and perfect the desired responses.

At birth the human baby, with its billions of cells in its cerebrum, is more helpless and more in need of its parents' care than any other baby animal. At the same time it is more capable of learning than any other animal. During its years of infancy, therefore, it is gaining experience which affects its later behavior. The broader and richer the experiences which the growing child has

What evidence of parental care is shown in this picture?

and uses, the greater is the number of impressions retained, and hence the greater the possibilities later for rich thinking, remembering, and planning.

How much a human being might learn is not known. Probably there are no limits to human learning. It is certain that nobody has ever developed more than a small fraction of the possibilities of which his brain is capable.

Self-test. 1. The animal having the most complex brain is *the elephant.*

2. The complex thinking which man can do is made possible by his possession of a complex --?--.

3. *Few* animals lower in the scale of life than man can form or change habits purposefully.

4. After a man has formed a habit, the habit is controlled by the *higher* centers of his *brain.*

5. It is *difficult* to change a habit unless one wants to change it.

6. Adults can gain intellectual knowledge *as* readily *as* children.

7. *Few* older people can learn, *though* they wish strongly to do so.

8. A student who is "*good*" in his school work is very likely to be "*poor*" in most other activities.

9. In general, the *less* complex the brain of an animal, the *longer* must be the period of infancy.

10. Probably the most intelligent of the animals other than man are (1) horses; (2) elephants; (3) dogs; (4) higher monkeys; (5) pigs; (6) cats; (7) chickens.

Self-test on Important Biological Terms

gray matter habit higher learning trial-and-error learning

Self-test on Biological Principles. 1. What illustrations can you give from this and the preceding chapter which seem to prove the principle "A reaction is successful if it aids an organism directly or indirectly to survive"?

2. Do the examples of trial-and-error learning given on pages 437–438 seem in general to prove the statement "The higher in the scale of life an animal is, the more complex the maze which it can learn"? Are there exceptions? Explain.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Explain how pleasure or annoyance aided the carp in learning to avoid a worm on a hook.

2. Why does a baby have to learn to walk?

3. What possible advantages over other animals has man derived from his erect posture?

4. State the seven factors involved in learning which are given under "Self-test on Understandings," pp. 439–440. Illustrate each by means of the statements concerning the meadow larks on p. 431 or by some observation of your own.

5. Can you explain step by step how one learns to drive an automobile?

6. Why is it true that man can learn as long as he lives, while dogs and other mammals can learn little after they have matured?

7. Suppose a person is inclined to lose his temper at the least provocation and to say things for which he is later sorry. What are the steps which he can use to break this bad habit?

8. In studying animal behavior investigators frequently use a "puzzle box," that is, a box from which an animal can escape only by performing some special act, such as pulling a string, pushing against a certain spot, raising a latch, and the like. Thorndike allowed a cat to learn how to get out of a certain puzzle box. He then put into the box another cat, which watched the first one escape. But the second cat was unable to learn from observing the first cat how to get out, though it watched the escape many times. Thorndike also had monkeys watch him open a box to see whether they could then open it by imitation, but almost without exception they could not. Can you explain these facts on the basis of the development of the cat's and the monkey's nervous systems?

9. How does learning differ from remembering?

10. Does memory play a part in all learning? Explain.

Exercises on Scientific Method. 1. *Recognizing Defects and Errors in Conditions.* Most people enjoy watching the behavior of animals and later telling what they have observed. They are likely to tell also what the animals thought or why they acted in the way they did. How much of such statements is likely to be scientific evidence? How much is practically certain not to be? Explain.

2. *Making Inferences and Planning Experiments.* A certain investigator carried on a learning experiment with a normal man, a defective man, six boys of varying ages, one defective boy, five monkeys, sixteen dogs, seven cats, and a horse. In this experiment the horse proved "stupider" than any of the other subjects. What conclusions might one draw from these facts? How would you go about testing these conclusions to find which was correct?

Exercise on Scientific Attitudes. Some people, called phrenologists, claim that they can tell one's character by the "bumps" on one's head and sometimes even claim to be able to tell from one's "bumps" the "past, present, and future." Are such claims scientific? (Look up phrenology in an encyclopedia or in a textbook of psychology.) What scientific attitudes should one possess in considering the claims of phrenologists?

Project 22. To make a maze or a puzzle box and find out how long it takes an animal to learn the maze or the box. Make a maze with a few turns and with a few choices of passages or make a simple puzzle box the door of which opens only when a string is pulled or when an animal pushes against one certain spot. Put some food at the outside door of the maze or just outside the puzzle box. Put into the maze or the box a cat, a white rat, a chick, or some other animal. Time it to see how long it takes to escape. Watch what sorts of movements it makes before it finally finds its way out. Allow it to eat some of the food; then repeat the experiment. Repeat the experiment several times a day until the animal has learned to escape with few or no false movements.

Consult some textbook on animal psychology if one is at hand to find out about the Hampton Court maze or other mazes and puzzle boxes which have been used in similar experiments in animal learning.

Special Report. Trained dogs were used for the protection of vital war plants and for other important purposes during the Second World War. How were the dogs trained for these special duties?

CHAPTER XXIII

Organs of Special Senses

Questions This Chapter Answers. 1. What sense organs does man possess? · 2. What is the nature of the senses in various animals? · 3. What are the structures and functions of the human sense organs? · 4. What is the importance of the senses in survival?

WHAT IS THE NATURE OF THE SENSES OF TOUCH, TASTE, AND SMELL?

Many sense organs. We are accustomed to think of the special senses as being five in number. The lower organisms have fewer than five senses, while the highest organism, man, has more than twice that many. The more familiar special sense organs of man include those for sight, hearing, taste, smell, touch (or pressure), heat, cold, pain, balance, and the sense of muscular effort (kinesthetic sense).

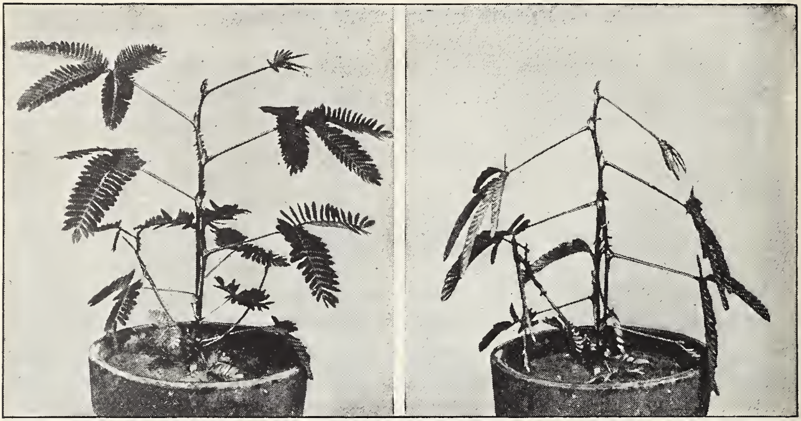
The senses depending on contact. The sense of touch, or pressure, is the most primitive of all the special senses. All the animals and even some of the plants possess this sense, even though the one-celled animals, and the plants that possess this sense, have no special organs of touch such as nerves. The leaves of the sensitive plant fold together quickly when anything comes in contact with them. It is thought that the contact in some way causes water to be withdrawn from certain cells near the bases of the leaves. Then as these cells collapse, the leaves droop for lack of support. The cells slowly regain their water, and the leaves assume their original positions.

Many of the Protozoa have certain parts of their one-celled bodies which are specially sensitive to touch. In *Paramecium* it is the cilia and in *Euglena* (see the Index) it is the whip-like projection (flagellum) that are sensitive.

In the simpler Metazoa special nerve endings in the skin serve as organs of touch. These are distributed over the entire bodies of the animals. These touch organs are of more than one kind, even in fairly simple animals, because they are sensitive not only to contact but also to heat and to pain. The antennae of animals like crayfish and insects are specially sensitive to touch.

In the higher animals there are four different kinds of nerves in the skin which respond to contact.

Experiment 58. Are there different nerve endings in the skin for the senses of pressure, pain, heat, and cold? On the skin of your forearm outline a small square in ink. Make a similar square on a sheet of paper. Secure a small wire hairpin or a small nail with a smooth point. Holding the nail in the other hand, run it lightly and not too rapidly back and forth over the skin marked by the square. Do you

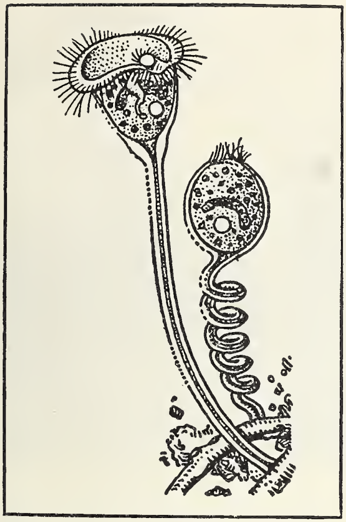


Sensitive plant before and after being touched. **Self-test on Biological Principles: Can** you explain how this figure illustrates the principle "Adaptations of structure or behavior which help the plant or the animal to survive are likely to persist"?

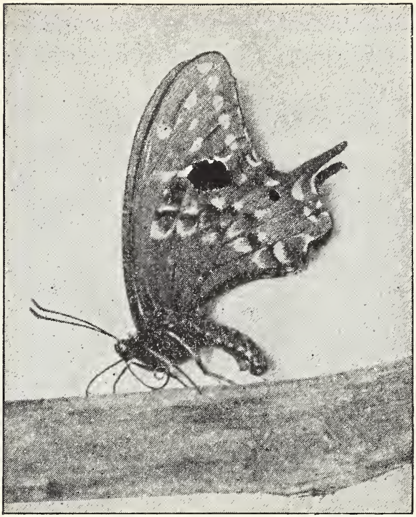
sometimes touch a spot which seems very sensitive? This spot is probably an ending of a nerve of pain. Put a dot on the record square in the corresponding spot. Heat the nail slightly, so that it is definitely warm. Pass it over the skin in the same way. Do you find spots especially sensitive to heat? Mark these with small circles on your record square. Cool the nail and try to find the "cold spots." Mark these with small crosses. Do you find any spots where you merely feel the nail without its causing sensations of heat, cold, or pain? If so, record the location of such spots with a cross inside a circle. Complete your record and put a legend below it which answers the question of the problem.

Experiment 59. Can you determine the positions of parts of your body by means of the muscular (kinesthetic) sense? Close your eyes and lift your arm, holding it in various positions. Do you know in each case the position in which your arm is? Repeat with your hand, finger, or leg. Do you know its position in each case? Can you determine how you know?

The senses of taste and smell. These senses are considered as chemical senses, since they depend on chemical reactions between the substances which are tasted or smelled and the organs which detect them. For the animals which live in water,—and this list would include most of the animals simpler than the insects,—the senses of taste and smell are believed to be practically the same. They are useful to these animals chiefly in securing food. With the lower organisms, moreover, the sense of touch is closely associated with smell.



Two vorticellas. The one at the left is feeding. Can you suggest what has just happened to cause the vorticella at the right to assume the shape it has?



Cornelia Clarke

Some butterflies taste with their feet. **Self-test on Scientific Method (Making Inferences):** Can you suggest any advantages which the butterfly may derive from this adaptation?

In many of the lowest forms it is not yet known whether the recognition of food is due to a sense of touch or a chemical sense of taste and smell.

Results of several experiments indicate that earthworms have a sense of taste and perhaps also of smell. Moreover, they have also a sense of touch. Thus, if placed on filter paper which is moistened with pure water, the earthworms will not burrow. But if the filter paper is moistened with water from the ground in which they live, they will burrow at once. Further evidence of a sense of taste is furnished by the fact that the earthworm prefers lettuce and cabbage to other kinds of food. Very small sense organs on the surface of the body, especially near the head end, may account for these reactions.

It is believed by one investigator that a certain land snail has its sense of smell in the ends of its horns and its sense of taste chiefly around its lips.

The mouth parts and perhaps also the antennae of the crayfish serve as organs of taste and smell. In still water the crayfish is not guided to food by its senses of taste and smell. In running water, however, it will move against the current, upstream, considerable distances and will find food from the taste or the smell of it in the water.

United States Department of the Interior

Young bald-headed eagles (Acadia National Park, Maine). The eagle is a bird of prey. Which of its senses should you expect it to depend on chiefly in locating food? Justify your answer

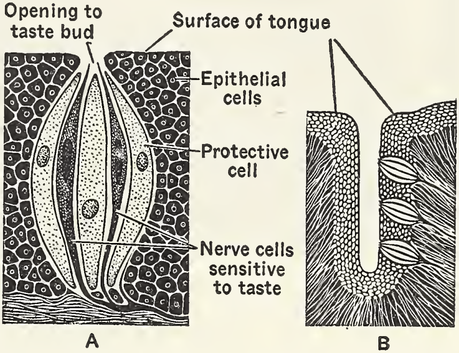
Many insects have a distinct sense of smell. This is located, it is believed, in the antennae. Bees are thought to be able to distinguish certain substances more readily than we can and to be better able to distinguish between two or more odors at the same time. The sense of smell has an important part in the mating habits of many insects, such as moths. The male moth is believed to detect the presence of the female by the sense of smell. Ants are believed to be able to distinguish between a considerable number of different odors.

The taste and smell senses of chordates. The senses of the lowest chordates are believed to be more like those of the earthworm than like those of the higher vertebrates or even of the highest invertebrates. Fish, however, are able to taste and smell to some extent. We know this from the fact that if similar samples of food, and of other substances which are not food, are put into the water, the fish choose the food. It is believed by some observers that salmon and other fish which live in the ocean but which come to fresh water to spawn are guided to the spawning grounds by the sense of taste, that is, by the differences in the amount of salt or possibly of other substances in the water.

Very little is yet known about the senses of taste and smell in the frog. Other amphibians, however,—for example, some of the newts and salamanders,—are able to locate food by these senses.

Of the reptiles, turtles have been observed to distinguish between various sorts of food, both when they are in the water and when they are out of it.

Birds have senses of taste and smell. These senses, however, are probably not very keen, since the bird depends chiefly on sight and hearing for locating food and detecting enemies. Some young chicks indicated that they possessed a sense of taste by "showing disgust" when they picked up orange peel instead of egg yolk. One investigator who studied twenty-seven of the thirty-five existing orders of birds came to the conclusion that in general the higher the order of bird, the less keen is its sense of smell.

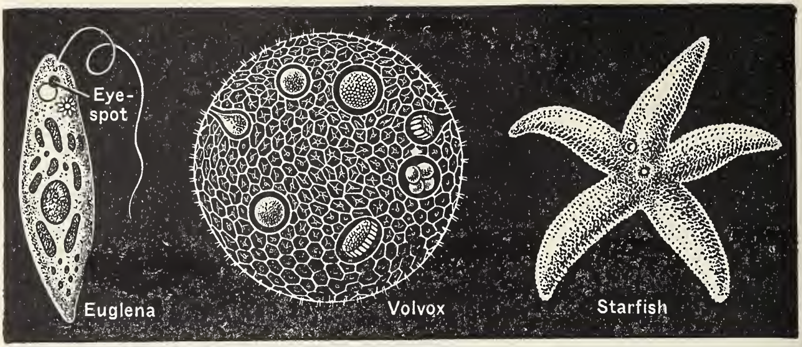


Taste buds. A, structure of taste bud; B, location of taste buds in the grooves of the tongue. In what ways are the taste cells protected? What advantages are derived from having them thus protected?

Most of the mammals have a very keen sense of smell. Wild animals depend on this sense chiefly to warn them of enemies and to tell them of the presence of their prey. Many of the mammals, the dogs especially, have a much keener sense of smell than man.

The organs of smell and taste in man. *A spot in each of the upper nostrils about the size of a dime contains the nerve endings which give man his sense of smell. Each of these special nerve cells has six or eight cilia upon the exposed end. It is believed that molecules or exceedingly small particles are carried to these nerve cells in the form of gases, and that these particles produce chemical reactions in these nerve cells. The nerves of smell, however, soon lose their ability to respond to a particular odor to which they are constantly exposed. For example, when a person first enters a badly ventilated room, he is conscious of many disagreeable odors. But if he remains for even a few minutes, his nerves of smell no longer respond to those odors, and he does not notice that the air is foul.

*The nerves of taste end in small buds (papillae). These are located in pits on the surface of the tongue and also to some extent on the roof of the mouth and on the walls of the throat. Only foods which will dissolve can be tasted, since the nerve endings are in little pits which only liquid can reach. The only substances which can be tasted are those that are sweet, sour, bitter, or salty. All other so-called tastes or flavors are really odors. This fact explains why



Animals with eyespots. Each cell in *Volvox* has an eyespot. The starfish has an eyepit, or eyespot, at the end of each arm. How do you explain the fact that these animals have eyespots instead of well-developed eyes?

foods lose flavor when one has a cold, for then the passages of the nose become so swollen and inflamed that air currents cannot bring food molecules to the nerves of smell.

Self-test. 1. Name eight special senses of man.

2. More organisms possess the sense of *sight* than possess any of the other senses.

3. Name four different kinds of sense organs which man possesses but which the Protozoa and sponges do not.

4. The chemical senses are those of *touch* and *taste.*

5. Certain *arthropods* are believed to have a keener sense of smell than man.

6. Many flavors which we think are due to taste are really due to --?--.

7. Man's sense of taste is located *entirely* on the tongue.

WHAT IS THE NATURE OF THE SENSE OF SIGHT IN VARIOUS ANIMALS?

The sense of sight. We have learned that nearly all plants and animals seem sensitive to light. Many of the lower animals, even a few of the Protozoa, have colored spots called eyespots, which seem more sensitive to light than do other parts of the body. But we cannot say that these animals really see. Their eyespots are not really eyes, though those of some of the lower Metazoa are fairly complex in structure. Animals with eyespots probably distinguish no more than changes between light and shadow.

An earthworm has no eyespot. Instead it has in its skin a large number of special nerve ends which are sensitive to light.

Cornelia Clarke

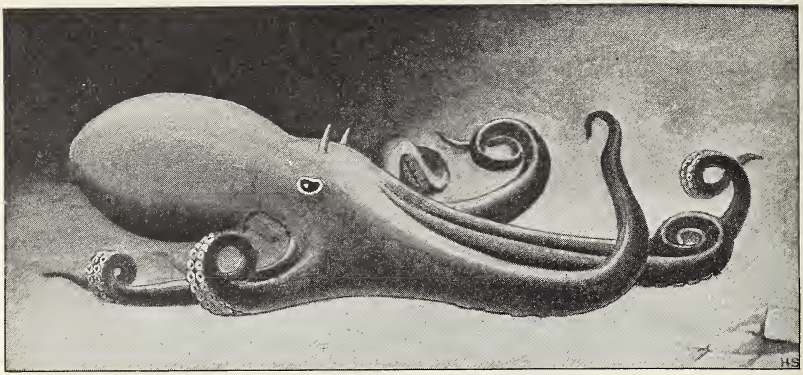
Hunting spider guarding her egg case. The spider has simple eyes. Are there always six eyes, and are they always arranged as are those of this spider? Find the answer to this question by examining with a lens or a reading glass the heads of various spiders

No true eyes are found in animals of the lower phyla. The only animals with true eyes are some of the higher mollusks, the arthropods, and the vertebrates. These eyes are of three sorts: (1) the simple eyes (ocelli) of insects and spiders; (2) the compound eyes of insects and crustaceans; (3) the lens type of eye, as in vertebrates and in such mollusks as the octopus and the cuttlefish.

Simple eyes. A simple eye consists of a bit of bulging, thickened skin (cuticle) which acts as a lens in bringing light rays to a focus on the retina, or sensitive nerve ends, which lie beneath. Nerves from the retina pass to the brain.

Simple eyes are more effective organs than the more primitive eyespots. Yet it is not yet definitely known how effective simple eyes are. There is considerable evidence which is believed to show that the animals with simple eyes can distinguish only general size and movement and can judge short distances.

Compound eyes. Compound eyes, such as those of most insects, are essentially a large number of simple eyes closely crowded together. Each one acts independently in focusing light rays. The result is an image many times repeated.



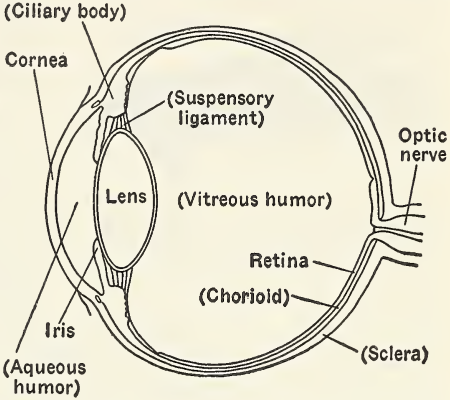
The octopus and its close relative the cuttlefish each have two highly developed eyes. Compare the eyes of the octopus with those of an insect. (See "How to Study," p. x)

The compound eye is believed to be useful chiefly in locating the direction of light and in detecting moving objects. Investigators are not agreed on whether the compound eye gives a fairly clear image or only general size and movement. Some investigators believe that insects, like the grasshopper, which have both simple and compound eyes, may use one form for seeing objects near by and the other for seeing objects farther away. Others believe that such insects use their simple eyes to detect sudden changes in the intensity of light. There is considerable evidence which seems to show that invertebrates in general are color-blind.

The lens type of eye. The lowest of the chordates have far more primitive organs of vision than many other animals lower in the scale of life. The amphioxus, for example, has simple eyespots. All the vertebrates, however, have the lens type of eye, that is, the same type as the human eye. This eye acts in such a way that a single image is clearly formed, much as a picture is taken by a camera.

Every vertebrate has two eyes only. Almost without exception fish, amphibians, reptiles, and birds have one eye on each side of the head. This arrangement is of value in permitting the animals to see more of their surroundings at one time. The higher mammals, including man, have their eyes placed more closely together on the front of the head. Such animals cannot see behind them, but they are better able to judge distances than animals with eyes farther apart.

How we see. *Light enters the eye through the pupil, which is an opening in the iris. The iris, the colored part of the eye, is made up largely of muscles, which regulate the size of the pupil. When the light is very bright, these muscles contract, making the pupil small. When the light is dim, the muscles of the iris relax, permitting more light to enter the eye. Just behind the pupil is the lens, which brings the light rays to a focus. The lens is elastic and is governed by small muscles. It is thinner when objects are far away and thicker when objects are near. Thus it keeps the image focused on the retina. In the retina are found the nerve endings of the optic nerve. These are affected when light rays are focused on them. The nerves transmit the stimulus to the brain, which interprets it as sight.



The human eye. Can you state the function of each of the labeled structures?

Self-test. 1. We should not expect to find true eyes in animals lower than (1) sponges; (2) Protozoa; (3) annelids; (4) mollusks; (5) chordates.

2. Arrange the following sight organs in order from most effective to least effective: (1) lens type of eyes; (2) eyespot; (3) compound eye; (4) simple eye; (5) nerve endings sensitive to light.

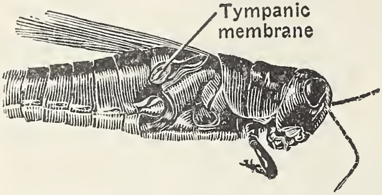
3. Every vertebrate has --?-- eyes.

4. It would be *difficult* to see, even with perfect eyes, if the nerves connecting the eyes with the brain were destroyed.

WHAT IS THE NATURE OF THE SENSES OF HEARING AND BALANCE?

What animals can hear? Darwin allowed earthworms to make their burrows in flowerpots, so that they could be carried from place to place. He found that if the pots were placed near a piano, the worms made no response whatever when music was played. If, however, the pots were placed upon the piano, the worms drew back into their burrows at once when a note was struck. This experiment indicates that the worms did not hear but that they responded to the jarring caused by the vibrations of the piano wires when these vibrations were carried through the piano case to the flowerpot. The sensation was probably received by the entire body and was more closely related to touch than to hearing.

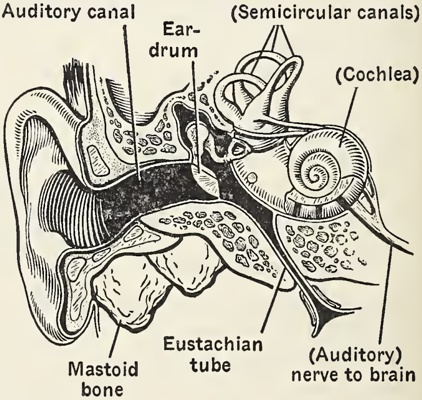
This and other experiments have convinced experimenters that most animals are sensitive to vibrations in the air, the water, or the soil which surrounds them. There are no experiments, however, which have proved that any animal which is lower in the scale of life than the insect really hears.



The hearing organ of a grasshopper. To what part of the human ear does this membrane correspond?

Hearing in insects. The hearing structures of different insects vary considerably. The finely branched antennae of gnats, mosquitoes, and other insects are supposed to serve as hearing organs. Certain organs on the abdomen of the grasshopper and on the front legs of crickets are supposed to serve the same purpose. Such an organ consists of a tightly stretched membrane (tympanic membrane). This membrane is thought to vibrate when sound waves strike it. In the pit beneath the membrane are nerve endings. These pick up the vibrations and carry the sensation to the brain.

How we hear. *There are three sections of the human ear: the outer ear, the middle ear, and the inner ear. As the sound waves which are gathered up by the outer ear strike against the ear-drum, they cause it to vibrate. The vibrations are carried across the middle ear by the successive movements of three small bones. The third of these bones fits closely against the thin membrane which separates the middle ear from the inner ear. As the bone vibrates it causes movement in the fluid which fills the inner ear (cochlea). These waves stimulate the endings of the nerves which line the inner ear. The impulses are then carried to the brain by the auditory nerve and are interpreted as sounds.



By using this diagram, can you explain how we hear?

Hearing in vertebrates. All vertebrates possess inner ears which are similar to those of man, though all do not have the special ear parts that make hearing possible. As with other structures, the ears of vertebrates become in general more complex the higher the animal is in the scale of life. Fish and snakes possess only the inner ear. Sound waves can reach this ear, therefore, only through the bones of the head. The frog has an ear-drum on the surface of its body. The ear of a bird is much like the ear of a mammal, except that the hearing part of the organ is less perfectly developed.

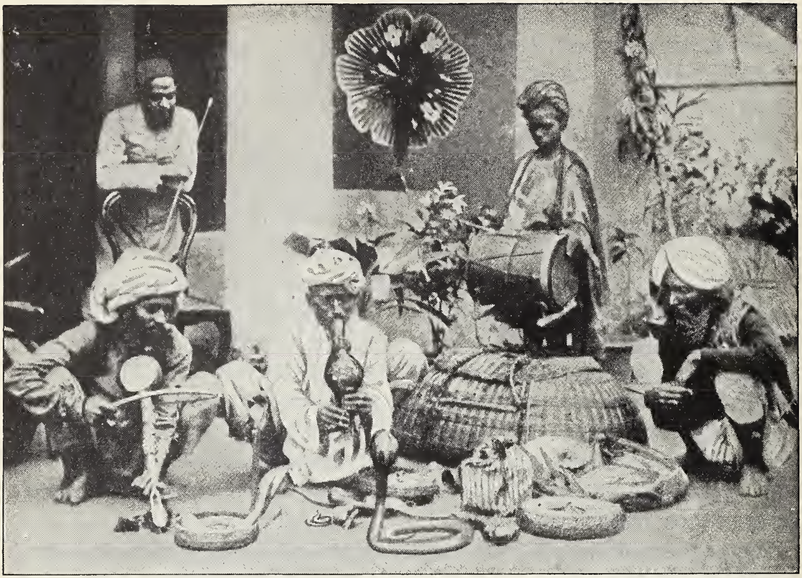
Fish are believed to hear the sounds which are made under water. Experiments with frogs, mud puppies, and other amphibians seem to indicate that these animals also can hear. Experiments with reptiles, however, indicate that some are able to hear and others are not. For example, one experimenter found that a certain lizard when not disturbed closed its eyes and opened them again at intervals of about half a minute. He therefore waited until the lizard had closed its eyes, and after about ten seconds he blew a note of a whistle. The lizard immediately opened its eyes. The experimenter repeated this investigation with the same lizard and with lizards of another kind, using different tones. The results were always the same. From these experiments he concluded that these lizards at least could hear. Another scientist, experimenting with rattlesnakes, and a third with turtles, found no evidence to indicate that either of these reptiles can hear.

Range of sounds. Scientists are not agreed with respect to the range of sounds which man can hear. The range of sounds is estimated at from about twenty vibrations per second to about thirty thousand vibrations per second. He cannot hear deeper or shriller sounds than these. Birds and mammals have a considerable range of sounds which they can hear. Some insects are believed to be able to hear sounds shriller than man can distinguish. Other animals are believed to be able to hear deep tones to which man is deaf.

The sense of balance. Most animals tend to remain right side up. With the plants and the lower animals the righting action is the result of one or more tropisms. It is not known what causes most of the animals to keep right side up. It is believed that some of the lower animals remain upright because the lower portions of their bodies are composed of heavier particles.

Crustaceans, such as crayfish and lobsters, have an organ of balance (called a statocyst) on the first joint of each of the small antennae. This organ consists of a pit lined with sensitive hairs and enclosing one or more grains of sand. As the animal changes position the grains of sand float about in the organ and touch new sets of nerves. Thus the animal becomes aware of changes in position and can keep itself in balance. When the exoskeleton is shed, the lining of the balancing organ is shed, too, and the sand grains are lost.

One experimenter placed a newly molted crayfish in a tank in which there were no solid particles except iron filings. Later he found that some of the iron filings were in the balancing organ of the crayfish. He knew this because



James's Press Agency, London

Hindu snake-charmers. **Exercise on Scientific Attitudes:** Does the evidence in this picture seem to agree with or to contradict that secured by the investigator of hearing in rattlesnakes? Which of the scientific attitudes (p. 624) should one possess in considering this evidence on the hearing of snakes?

a magnet attracted the animal's head. From these observations he concluded that a crayfish itself places the sand grains in its balancing organ.

Insects and spiders have no organ of balance corresponding to that of crustaceans. Their ability to keep right side up may possibly be due to reaction to light or to the action of gravity, owing to the way in which their body materials are arranged.

In all vertebrates the organ of balance is located in the ear, though the sense of vision too may be of great help in maintaining balance. In man and other vertebrates the organ of balance is part of the inner ear. This structure consists of three tubes (called semicircular canals, see p. 460). These tubes are placed at right angles to one another. They are filled with a liquid, and their walls contain very sensitive nerve endings. When the head is moved, the position of the fluid is changed, and a different set of nerves is affected. Thus the brain learns of the general position of the body. It then directs the movements necessary to keep the body in balance.

Survival values of the senses. The senses are necessary for the survival of animals. An unusual stimulus may reveal an enemy the presence of which might not otherwise be discovered. If, therefore, an animal is suddenly touched, it is likely to flee, to get ready to fight, to contract, to roll up in a ball, to play dead, or to react in any one of a number of other ways, depending on the animal. But whatever reaction the animal makes is most likely to aid in protecting it. Similarly the organisms which possess the senses of heat and cold are guided to an environment which possesses the temperature conditions best suited to their successful living. They are warned in time to escape if the temperature conditions are changing to an extent which might prove harmful to them.

The sense of pain also aids animals in avoiding conditions which might prove harmful. This sense in a certain respect acts as a check upon the senses of touch, heat, and cold. Thus the sense of pain warns the animal when the contact is too violent or when the heat or cold becomes too intense. If the pain caused by a certain experience is sufficiently great, the animal is not likely to repeat the experience. Keen eyesight, hearing, taste, and smell likewise give warning of unfavorable conditions and guide the animal to food or other necessities of life. The sense of balance enables the animal to keep in the position which helps it best to live successfully.

As was stated in the preceding chapter, organisms differ more or less in every respect from every other organism of the same kind. Some animals must therefore inherit much keener senses than other animals of the same kind. An animal which lacks any of the senses necessary to successful life in its environment is less likely to grow to maturity and to have offspring than an animal which is better equipped with these senses. Under natural conditions, therefore, only those animals which are better equipped than others of their kind are likely to grow to maturity and have offspring. Hence there is always in nature a survival of the fittest and an elimination of the unfit.

Self-test. 1. Scientists believe it *possible* that *many* animals as simple as mollusks and coelenterates hear.

2. Insects are believed to hear by means of organs located on (1) their heads; (2) their hind legs; (3) their front legs; (4) different parts of different insects; (5) their antennae.

3. We hear *little* except when the bones of the middle ear vibrate.

4. In vertebrates the organ of --?-- is always located in the ear, but the organ of --?-- is not always present.

5. The hearing organ of mammals is *somewhat less* highly developed than that of the other classes of vertebrates.

6. Man cannot hear vibrations that are too --?-- or too --?--.

© Asahel Curtis

Elk near Standing Creek, Washington. What evidence is there in this picture that elk depend on keen eyesight and hearing as aids to survival?

7. We should find it *difficult* to maintain our balance, even though the organs of balance were perfect, if the nerves connecting these organs and the brain were destroyed.

8. There are various sorts of organs of *balance* located in various parts of different animals.

9. In general, the *keener* the senses, the *greater* are the chances for survival.

Self-test on Important Biological Terms

auditory nerve
compound eye
iris
lens
optic nerve
pupil
sensation
sense organ
simple eye

Self-test on Biological Principles. Can you find the statement of a principle on page 455?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why have the bulging eyes of frogs a greater survival value than they would possess if they did not bulge?

2. Besides the usual eyelids, the frog has a transparent third eyelid (nictitating membrane), which can be drawn up when the animal is under water. Of what survival value is this adaptation?

Exercises on Scientific Method. 1. *Making Inferences and Proposing Experiments.* Charles Darwin, a famous English scientist, in his book *A Naturalist's Voyage in H. M. S. Beagle*, describes an interesting experiment which another naturalist had tried with turkey buzzards. These birds eat decaying flesh, or carrion. The naturalist covered with a thick canvas cloth some flesh which had decayed sufficiently to have a very strong odor, and placed some pieces of the meat on the cloth. "These the carrion-vultures ate up, and then remained quietly standing, with their beaks within an eighth of an inch of the putrid decaying mass, without discovering it." When a small tear was made in the canvas, the birds discovered the meat at once. But when "the canvas was replaced by a fresh piece, and meat again put on it," this meat "was again devoured by the vultures without their discovering the hidden mass on which they were trampling." What inference would you draw from these observations? Why was this experiment repeated? Can you suggest other check experiments similar to this one which would enable you to tell whether your inference was correct? Would you approve the following as a conclusion from the experiment: "All carrion-eating birds would have reacted to the same situation just as these vultures did"? Justify your answer.

2. *Inventing Experiments.* It is said that we taste sweet substances at the tip of the tongue, sour substances at the sides, bitter at the very back, and salt all over. Plan an experiment to test the truth of this statement.

3. *Making Inferences.* Certain investigators placed a grasshopper in one end of a narrow glass tube and a hunting spider at the other end. The spider's movements changed when it had advanced to within eight inches of the grasshopper, and at four inches it leaped upon its insect prey. How many possible explanations can you think of which might explain this behavior? Why can we not be certain that any of these explanations is the correct one?

4. *Evaluating Conclusions.* How many reasons can you give to explain these two statements: "It is very difficult to study the vision of animals, especially the lower ones. Practically nothing is yet known as a *fact* about how they see or how well they see"?

5. *Making Inferences.* When a mother hen finds food she makes a certain fairly high-pitched sound. The chicks immediately run to her and eat the food. When she sees a hawk flying overhead, she utters a low-pitched warning, whereupon the chicks scamper and hide. On the basis of these facts, would you accept this conclusion: "Birds are able to hear all sorts of sounds"? Justify your answer. Are these responses of the young birds learned or unlearned reactions? Justify your answer.

6. Which of the elements of scientific method (see p. 625) are illustrated in the experiments to determine whether lizards can hear?

7. *Evaluating Data and Inventing Experiments.* This exercise must start with some careful observations. Blindfold a member of your class; then have him close one ear while you bring a vibrating tuning fork slowly toward the other. Have him tell you when he first hears the fork. Measure with a ruler the distance of the fork

from his ear. Then repeat the experiment with his other ear. Repeat the experiment with other members of the class. Are both ears of most of the boys and girls equally acute? Is there a wide or a narrow range of difference in the distances at which different members of your class can hear the sound? If you have a pet, such as a dog or a cat at home, try to make the same observations on it that you have made with your classmates and compare the results with the others you obtained.

Now apply your knowledge of the elements of scientific method: What reasons can you think of which might cause you to doubt the accuracy of your results? Is any check experiment needed in order that you may be reasonably sure that your results are correct? Why? If so, what sort of experiment would you perform? Were any controls used in the observations on the hearing of your classmates? Justify your answer.

8. *Making Hypotheses and Checking Them with Further Observations.* What is your hypothesis (see the Glossary) with respect to this question: "Does one distinguish such foods as onion, apple, and potato by taste alone? by smell alone? or by a combination of taste and smell?" Blindfold a member of the class and have him hold his nose tightly. Then place upon his tongue a small piece of apple, onion, or potato. Can he tell which it is? You can use any substances that do not have a conspicuously salty, sweet, sour, or bitter taste and that are enough alike in texture so that one cannot feel the difference. Try the same experiment with maple sirup, cane-sugar sirup, and sugar sirup flavored with vanilla extract. Do the results of these observations indicate that the hypothesis you made is the correct one?

Special Reports. 1. Did you ever "see opposite colors"? If you will stare intently at a black object on a white background for a minute or so and will then either close your eyes or look at a light-colored wall, you will think you see a white object of the same shape as the black one. If then you will stare at a white object on a black background, as at first, you will think you see a black object when you look away or when you close your eyes. Similarly, after you have stared intently at a red object for a while and then look away, you will see a similar green object. After staring at green you will see red. After staring at blue you will see yellow; after yellow, blue. These observations have to do with "retinal fatigue." Look up retinal fatigue in a textbook of psychology or in an encyclopedia.

2. Have you ever investigated the "blind spot" in your eyes? Draw two large dots about three inches apart on a sheet of paper. Hold the paper at arm's length. Close your right eye and with your left eye look at the right-hand spot as you bring the paper slowly toward your eye. For part of the distance you will see both dots. Then one will disappear because its image is falling on the blind spot in your left eye. Repeat with the left eye closed. Look up "blind spot" in a text-book of physiology or of psychology.

3. On page 433 is a picture of a "seeing-eye" dog leading its blind master across the street. Report to the class how these dogs are selected and trained. You can probably find out from any institution for the blind where you may obtain this information.

4. There are several types of color blindness. Consult textbooks of psychology or an encyclopedia to find out what the different types are; how common they are; and whether they are more or less common among men than among women. Find out what type of color blindness would be a serious handicap and danger to drivers of automobiles, and whether your city traffic department has any tests for color blindness which it gives to those who apply for driving licenses.

5. What is Braille? How are blind people taught to read? What books and magazines are provided for blind people? Your school or city librarian can probably furnish you information for answering these questions.

6. Helen Keller is a famous woman who overcame the handicaps of deafness and blindness from early life. Find out how Miss Keller was taught to communicate with other people. Report other interesting events in the life of this remarkable woman.

7. During the earlier part of the Second World War many of our merchant ships and troop transports were sunk by enemy submarines. Our scientists invented a "mechanical ear" with which to detect the presence of submarines and determine where they were. Explain the operation and construction of the "mechanical ear."

8. Cats cannot see until several days after they are born. What animals are thus born "blind," and how many days elapse after they are born before their eyes are open? Consult books of natural history.

Reference Books

CALDWELL, OTIS W., SKINNER, CHARLES EDWARD, and TIETZ, J. WINFIELD. *Biological Foundations of Education.* Ginn and Company, Boston.
ROBINSON, J. H. *The Mind in the Making.* Harper & Brothers, New York.
TROW, W. C. *Introduction to Educational Psychology.* Houghton Mifflin Company, Boston.
WASHBURN, M. F. *The Animal Mind.* The Macmillan Company, New York.

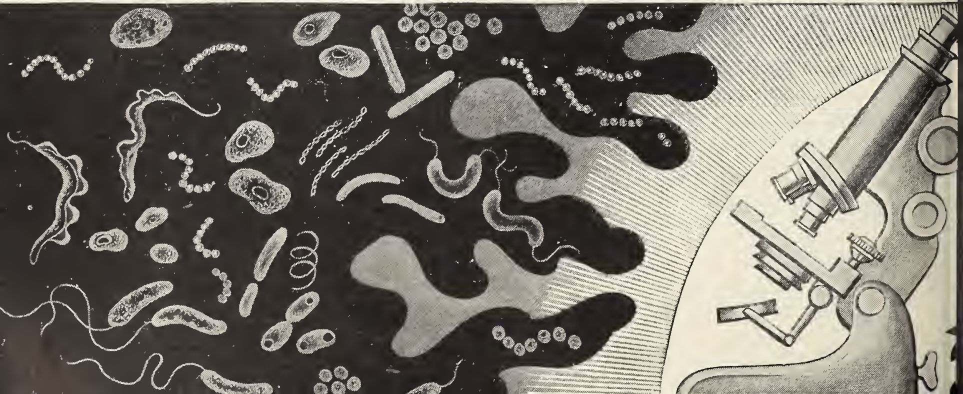
Motion-Picture Films

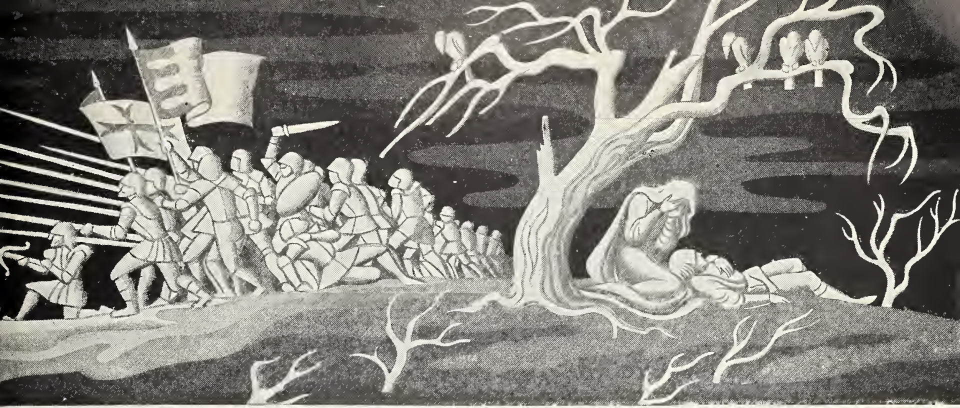
Nervous System. Erpi Picture Consultants, New York.
How You See. Bray Pictures Corporation, New York.
Reactions in Plants and Animals. Erpi Picture Consultants, New York.

UNIT VII · THE CONTROL OF DISEAS

There are three great agencies which tend to prevent rapid increases of population. These are war, famine, and disease. Famine often follows war; and disease always accompanies and follows both war and famine.

Throughout the history of mankind, there have always been serious diseases. In the Bible are accounts of pestilences which afflicted vast numbers of people. It is said that malaria and plague had as big a part in the conquering of Rome as did the wild tribes from the north. Various terrible diseases under the vague and general name of *plague* were common in Europe during many centuries. One of these, the Black Death of the fourteenth century, is estimated to have killed more than three fourths of the entire population of England, and one fourth of all the population of Europe, of that time.





ND THE IMPROVEMENT OF HEALTH

Serious diseases still break out from time to time in various parts of the world. Also, there yet remain a number of serious diseases of which the causes and the cures are not known. But the terrible pestilences so common in earlier times no longer sweep through the more civilized countries.

Various branches of biological science which are concerned with the improvement of health and with the decrease of sickness have won notable victories in the war against disease. It is a warfare, however, that can never cease. If science should relax its efforts for even a short period, the dread diseases of the past would regain their power and in our crowded cities would exact a greater toll of life than ever before.

This unit presents some of the most important triumphs of biological science in its efforts to prevent and to control disease.

CHAPTER XXIV

The Control of Disease

Questions This Chapter Answers. 1. What is meant by a biological "friend" or "enemy"? · 2. How did knowledge of bacteria grow? · 3. What are communicable and noncommunicable diseases? · 4. How are communicable diseases spread? · 5. Are communicable diseases inherited? · 6. How may the body be guarded against attacks by disease germs? · 7. How does the body acquire immunity to disease? · 8. Can science aid the body in acquiring immunity?

HOW DO VARIOUS MICROORGANISMS HELP AND HOW DO THEY INJURE MAN?

Biological "friends" and "enemies." No organism except man and perhaps some of the higher animals helps or hinders another through intention. Friendship and enmity, as understood in human relations, do not exist among living things in general. Each organism is engaged in its own struggle for existence. With few exceptions, it takes advantage of every favorable condition in its environment, without consideration for the welfare of other plants and animals. Certain of its activities may prove useful to other organisms. Others may prove more or less harmful. But it must survive by its own efforts in the competition with other living things.

Spores of the ringworm mold on human hair.[1] **Special Report:** How are such diseases as ringworm and "athlete's foot" spread from person to person? How may their spread be prevented? How are such diseases treated? (Consult a physician)

It is necessary to keep these facts in mind in speaking of our friends and enemies among plants and animals. They are friends only in the sense that their activities are useful to us. They are enemies only in the sense that their activities are injurious to us.

It is difficult to realize that some of man's most active and powerful enemies are small organisms. In fact, probably the most important are parasites, such as certain bacteria, molds, yeasts, rusts, smuts, and a few Protozoa. Bacteria cause serious diseases, such as tuberculosis, diphtheria, and pneumonia. Molds cause ringworm of several types, including "athlete's foot." The spores of a few other varieties of mold, upon entering the lungs, are able to live there as

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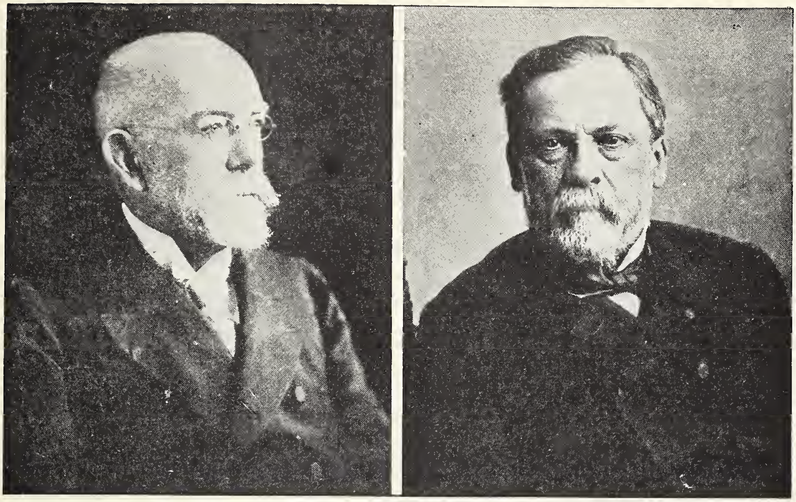
[1] From H. W. Conn, *Bacteria, Yeasts, and Molds in the Home*, Ginn and Company.



Robert Koch and Louis Pasteur. **Special Reports:** The scientific work of these men

parasites and sometimes cause death. Some diseases of the skin and lungs are caused by yeasts. Rusts and smuts attack some of our food plants. They are therefore of great importance to man because they compete with him for his food supply. Sometimes, moreover, serious poisoning results from eating rye which has been attacked by smuts. Certain Protozoa are responsible for some of man's most dangerous diseases, such as malaria.

Some diseases are caused by organisms so small that they will pass through a porcelain filter. Such an organism is therefore called a filtrable virus. It is known that these viruses are organic, but the exact nature is not yet fully known. Smallpox, rabies, influenza, and perhaps colds may be caused by these viruses.

How knowledge of bacteria grew. A study of fossils proves that bacteria much like those of the present day lived on the earth many millions of years ago. Indeed, they are thought by some scientists to have been the first living things upon the earth. Yet seventy-five years ago few people had ever heard of bacteria. Some of the scientists had learned to recognize a few forms under the microscope, but they considered the bacteria and all sorts of other minute organisms of various kinds as belonging in one group. Practically nothing was then known about how the bacteria lived, what they ate, or how they affect other living things. Bacteria were nothing more than scientific curiosities. They were interesting chiefly because, small as they were, they were nevertheless known to be living creatures. Nobody then suspected that they bore any relation to the welfare of man.

Accurate scientific knowledge of bacteria dates from the work of a German scientist, Koch, and a French scientist, Pasteur. These men reported their studies of bacteria during the second half of the nineteenth century. The work of these and many other scientists finally established beyond question the relation of certain kinds of bacteria to certain diseases.[1]

Self-test. 1. An organism which competes with man for energy is called an --?-- of man.

2. Organisms that cause diseases are *chiefly saprophytes.*

3. The worst of these enemies of man are (1) bacteria; (2) yeasts; (3) molds; (4) rusts; (5) smuts.

HOW ARE COMMUNICABLE DISEASES SPREAD?

Communicable and noncommunicable diseases. *The communicable diseases are those which can be contracted directly or indirectly from people who have them. Such diseases are commonly called "germ" diseases. The germs which cause them, however, are not always bacteria. Sometimes, as has been stated, the germs are molds or yeasts, sometimes Protozoa, certain of the worms, or filtrable viruses.

There are a number of very serious diseases which are not due to bacteria or to any other living organisms. Such diseases probably develop because various tissues and organs are no longer able to carry on their work effectively. These diseases include diabetes, diseases of the heart and of the kidneys, and hardening of the arteries (arteriosclerosis). They are known as noncommunicable diseases because they cannot be contracted from people who are sick.

How communicable diseases are spread by people. *Most of the communicable diseases are contracted more or less directly from people who have the diseases. Whenever a person talks, he may spray into the air innumerable droplets, that is, minute drops, of saliva and mucus which are laden with bacteria. When he coughs or sneezes, the number of bacteria-laden particles and the distance to which they are discharged are both greatly increased. Hence, whether a person knows he is ill with a communicable disease or not, he should always protect others by covering his mouth and nose with a handkerchief whenever he coughs or sneezes. Spitting, like coughing or sneezing with the mouth uncovered, is neither a decent nor a sanitary practice, because it is a ready means of spreading disease.

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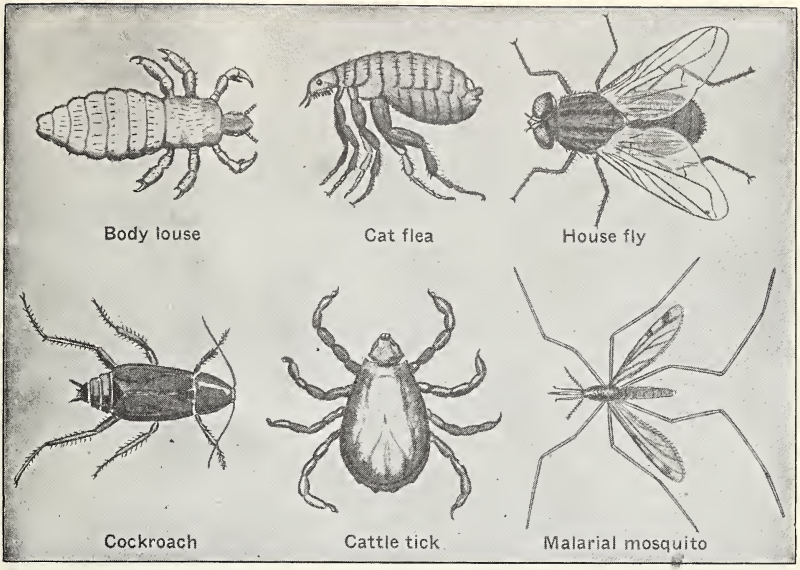
[1] To THE TEACHER. At the end of this chapter studies are suggested dealing with Pasteur. Koch, and Lister. Some pupils may find it useful to make those studies at this point.



Insects that carry germs. Name one or more kinds of disease germs which each of these animals may carry

Serious diseases (such as diphtheria, scarlet fever, tuberculosis) and colds can be readily contracted through kissing. A single kiss on the mouth has been known to transfer to a baby disease germs which later caused its death.

The germs of some diseases are spread through the excreta[1] of persons who are sick with the diseases. Hence these excreta should be sterilized with a germicide, that is, a germ-killing substance, such as formaldehyde solution or bichloride of mercury. Germs are also carried on clothing. Therefore the clothing worn by a person while he is suffering with a serious communicable disease should be sterilized. If this cannot be done, the garments should be burned.

There are certain people who are called "carriers of disease." Some of these people have themselves had a germ disease and have recovered from it, while other "carriers" may never themselves have been sick. Nevertheless they carry the germs about and can infect other people. Most of them do not realize that they are a source of danger. Diphtheria and typhoid are two serious diseases which are readily spread by such carriers.

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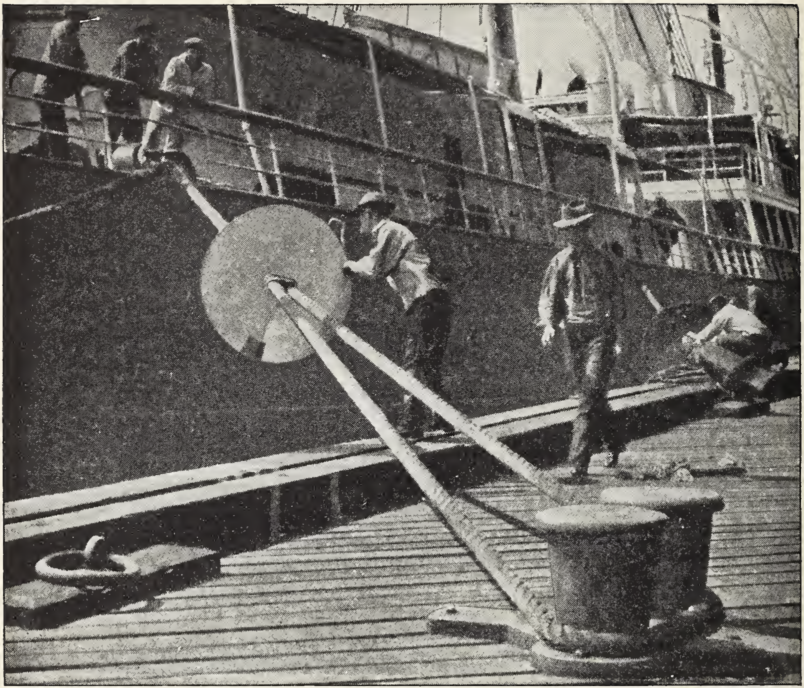
[1] *Excreta* (ĕx krē′tȧ): the waste materials from the alimentary canal.



Galloway

Rat guards on mooring ropes. What other ways can you suggest by which rats might be prevented from bringing plague germs into the country?

How communicable diseases are spread by animals. 1. *As victims of the disease.* People sometimes contract serious diseases from household pets and domestic animals which are sick with the diseases. Diphtheria and other diseases may thus be transmitted[1] by cats, dogs, rabbits, guinea pigs, and birds. Also, tularemia may be spread by contact with rabbits having this disease.

2. *As hosts of the disease parasite.* Certain animals, such as the malarial mosquito and the yellow-fever mosquito, act as hosts for certain parasites. These parasites must live a part of their lives in these animals and the rest in the bodies of human beings. In such cases both the man and the mosquito are hosts of the parasite. Such diseases can be eliminated only by (1) exterminating animal carriers or (2) preventing their coming in contact with human beings.

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[1] *Transmit* (trăns mĭt′): to send or convey from one place to another.

3. *As carriers of insect parasites that transmit disease parasites.* Another class of animal carriers transmit serious diseases by harboring insect parasites which transfer the germs to man, although the insects do not themselves serve as hosts to the germ. For example, bubonic plague is a disease of rats, ground squirrels, and sometimes of rabbits and guinea pigs, as well as of man. Man, however, cannot contract the disease directly from any of these animals. He must become infected with the bacteria through the bite of a flea, thus: If a flea bites an animal which is suffering from plague, it takes the plague germs into its digestive system. If later the flea bites a human being, the active germs in the flea's excreta may find their way through the wound made by the flea. Thus they may gain entrance into the victim's body.

Bubonic plague is common in China and especially in India, where it kills an appalling number of people every year. There are occasional outbreaks in certain sections of the United States. Health authorities cannot entirely prevent such outbreaks, because the animal carriers cannot be completely controlled. Rocky Mountain spotted fever is contracted through the bite of a tick which is a parasite on many animals.

4. *As mechanical carriers.* Still other animals, such as flies, lice, and cockroaches, do not themselves act as hosts, but carry the germs on their feet and bodies or in their excreta. Such pests can be fought successfully only (1) by keeping our bodies and clothing, our homes, schools, and places of business as clean as possible, (2) by screening our homes, (3) by destroying the animals themselves, and (4) by destroying their breeding places.

The housefly and the cockroach carry the germs of typhoid, tuberculosis, and many other dangerous bacterial diseases. In addition, they carry several kinds of parasitic worms. Body lice, which thrive and multiply wherever proper cleanliness and sanitation cannot be maintained, carry trench fever and typhus fever. More than a million people died of typhus fever as a result of the First World War, and enormous numbers have already died of it in the conquered countries and in the battle areas of the Second World War.

Pets which carry germs in their fur should be classed as mechanical carriers of disease. Sometimes such pets may become serious sources of danger to their owners and the community.

How communicable diseases are spread through water. *Even rain water may contain bacteria and other small organisms washed from the dust of the air. This fact is not surprising when one learns that bacteria and spores of plants may be carried in air as high as two miles above the ground. The germs of serious diseases, however, are not often found in water unless the water has become contaminated with human excreta. Serious diseases which can be spread through drinking water are typhoid, cholera, and dysentery.

Food market in the streets of a great city. What kinds of fruits especially should be protected from street dust?

Some of the most serious epidemics of typhoid have started from a single patient whose excreta found their way into a city water supply. The toilets of trains and airplanes, unless equipped to retain the wastes, are likely to be the means of spreading such contamination into streams and lakes which serve as sources of water.

How communicable diseases are spread through food. Many diseases may be transmitted through food. Among such diseases are typhoid, tuberculosis, scarlet fever, diphtheria, septic sore throat, and intestinal diseases of children. Probably the chief source of such infections[1] is milk. The properties which make milk a valuable food for human beings make it also an ideal food for bacteria. As a result, most known varieties of bacteria may sometimes be found in milk. Butter and cheese, which are milk products, are unlikely to contain dangerous bacteria, except those of tuberculosis and of undulant fever.

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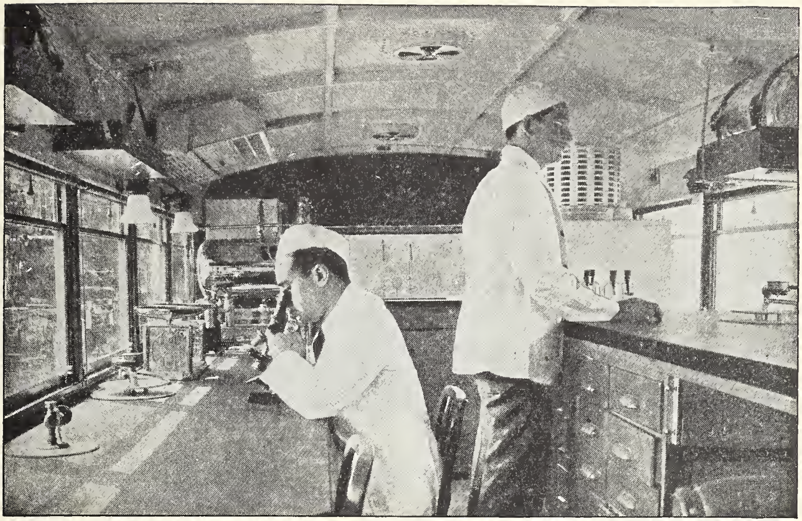
[1] *Infection* (ĭn fĕk'shŭn): act of contaminating with disease germs or state of being so contaminated. *Infectious* (ĭn fĕk'shŭs): able to cause an infection.



State of New York Department of Health

A milk "Labmobile." What advantages has this laboratory?

*Several precautions should be carefully observed in connection with the milk supply. (1) The cows must certainly be healthy. (2) The conditions in which the milking is done should be as sanitary as possible. (3) Those who work around the milk should be healthy. In some states and cities dairy and creamery workers are required to have certificates stating that they have no diseases which are likely to be spread through the milk. (4) The milk should be protected from contamination while it is being prepared for distribution and is being sold. (5) The milk should be kept cool and clean after delivery to the homes as well as before.

Excepting perhaps the highest grades of raw milk, the only safe milk is that which is pasteurized. In this process the milk is heated to a temperature of about 140° to 150° F for a period of thirty to forty-five minutes. It is then cooled. This process kills most of the dangerous bacteria with very little injury to the milk as food.

Are communicable diseases inherited? It is a rather common belief that many diseases are inherited by children from their parents. Tuberculosis, for example, seems to "run in families." However, all the evidence that scientists have been able to collect indicates that such diseases are not inherited. In fact, very few diseases are inherited. If a child develops a disease which one of its parents had, it probably contracted the disease from the parent after birth.

***Summary.** The germs of communicable diseases gain entrance to the body mainly

1. Through the respiratory system.
2. Through the digestive system.
3. Through the skin.

Such germs are spread

1. By people sick with the disease, chiefly.
2. By animals
    - *a.* Which themselves have the disease.
    - *b.* Which act as intermediate hosts for the germ.
    - *c.* Which act as necessary carriers of insect parasites that transmit the disease.
    - *d.* Which act as mechanical carriers.
3. Through the water system.
4. Through food, especially milk.

Few diseases are inherited.

Self-test. 1. *All* bacteria are germs, and *all* germs are bacteria.

2. *All* diseases that are "catching" are caused by organisms.

3. Coughing with uncovered mouth and spitting are ways in which *noncommunicable* diseases are spread.

4. *Some* people are able to spread disease without themselves becoming sick.

5. Name and give an illustration of each of four ways in which animals spread diseases.

6. A disease which may be readily contracted from water which is polluted with sewage is (1) mumps; (2) rheumatism; (3) typhoid fever; (4) anemia; (5) rickets; (6) heart disease.

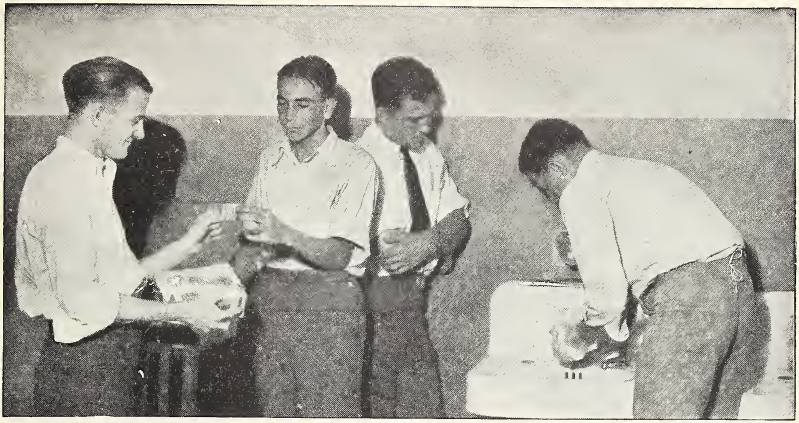
7. Select from the following the two items which do not belong with the rest: (1) typhoid fever; (2) trichinosis; (3) scarlet fever; (4) "athlete's foot"; (5) septic sore throat; (6) tuberculosis; (7) rickets; (8) diphtheria; (9) communicable diseases.

8. Name five ways of protecting the milk supply from dangerous disease germs.

9. *Many* diseases can be passed on to the child before it is born.

HOW MAY WE GUARD AGAINST ATTACKS BY DISEASE GERMS?

Guarding the body against attacks by germs. *Bacteria and other organisms causing disease cannot produce disease except under certain conditions. Not only must they gain entrance to the body, but they must also reach the particular organs or structures which they are able to attack. Some protection



Cleanliness Institute

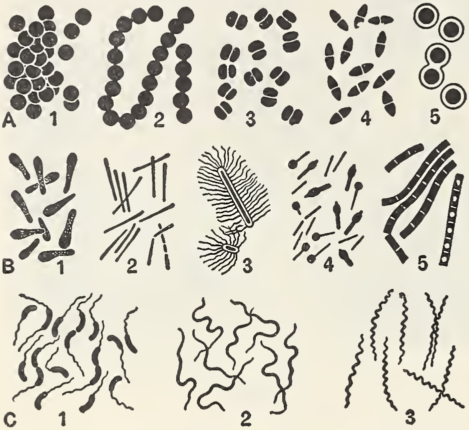
Inspection of hand-washing before pupils enter the school cafeteria. What provisions for hand-washing have you in your school?

can therefore be gained in the following ways: (1) by destroying bacteria and other organisms which might cause disease; (2) by sterilizing all scratches and wounds, even the smallest; (3) by observing rules of personal cleanliness and of sanitation; (4) by quarantining people who have dangerous, easily transmitted diseases; and (5) by making sure as nearly as we can that our food and water are free from harmful bacteria and other harmful organisms.

1. *By destroying germs.* Dishes should be thoroughly scalded after they are used. In case some member of the family is suffering from some communicable disease, the dishes used by the sick person should be kept separate from those of the rest of the family and should be thoroughly boiled after each meal. The discharges from the noses and mouths of patients suffering from colds, influenza, or other serious diseases should be deposited in paper handkerchiefs and later burned. The excreta of typhoid-fever patients should be disinfected by the use of such a disinfectant as bichloride of mercury or formaldehyde solution. All bed linen and under-garments of sick people should be boiled.

2. *By sterilizing scratches and wounds.* Tetanus, or lockjaw, is a dangerous disease, the germs of which enter through wounds. The bacteria which cause tetanus grow best in wounds from which air is excluded. It is never safe, therefore, to cover a wound with adhesive tape. A sterilized-gauze dressing, held in place by adhesive tape, is the best protection against further infection. Bacteria which cause infections may enter the body through any

scratch, cut, or wound. It is important, therefore, to sterilize all such breaks in the skin. Tincture of iodine is an almost certain means of killing germs in wounds. There is, however, one danger in the use of iodine. If too much of the alcohol in which the iodine crystals are dissolved evaporates, the iodine may become so concentrated that it will "burn" and injure the tissues. In spite of its disadvantages, however, tincture of iodine of the proper strength is probably the best household antiseptic, or substance that prevents infections.



The three groups of bacteria, magnified from a thousand to several thousand times. A: 1, clusters (staphylococci), found in abscesses; 2, chains (streptococci), cause of some acute infections; 3, (meningococci), cause of cerebro-spinal meningitis; 4, one of several types of germs (pneumococci), each of which causes pneumonia; 5, spore state, in which many bacteria are difficult to kill because of the protective covering. B: 1, diphtheria bacilli, with characteristic "Indian club" shape; 2, tubercle bacilli, human type; 3, typhoid bacilli, stained to show flagella; 4, tetanus bacilli, cause of lockjaw (slender rods develop characteristic "drumstick" spores); 5, anthrax bacilli, with spores developing in chain of rods at the right. C: 1, bacteria producing Asiatic cholera; 2, the form causing relapsing fever; 3, another disease-producing form. Can you find in this picture examples of each of the types of bacteria shown on page 132?

3. *By observing rules of cleanliness and sanitation.* Germs thrive in filth. Dirty clothing and dirty homes are likely to harbor innumerable bacteria. Hands, touching, as they do, all sorts of germ-laden things, are certain to be covered with bacteria. The use of plenty of soap and water is a good means of protecting health, since washing removes germs.

An important step toward sanitation is the elimination of flies. These breed in open outdoor toilets, manure piles, garbage piles, or any other deposits of filth. The vaults of outdoor toilets should be made and kept fly-tight and should be frequently sprinkled with liberal quantities of chloride of lime or dust. Barnyard manure should be kept in fly-tight boxes or bins until it can be spread upon the ground. If spread thinly it soon dries. Flies cannot breed in dry filth. Garbage and other refuse should be collected frequently and regularly and should be buried, burned, or disposed of in some other sanitary way.

Disease germs are spread by dust. Bare floors should therefore be swept with a vacuum sweeper and afterward polished with an oiled dust mop. Carpets and rugs should be swept with a vacuum sweeper, and the contents of the dust bag should be burned. Dusting is most effectively and safely accomplished by the use of an oiled dust-cloth or a treated dusting paper.

*4. *By quarantining.* In most places quarantine is demanded by law in cases of serious communicable diseases, such as smallpox, diphtheria, and scarlet fever. If the patient remains at home, the members of the household are not permitted to leave the house, nor are visitors allowed to enter it. In the hospitals are special "contagious wards," where those sick with serious communicable diseases are kept away from others who might contract the diseases. Those who have been exposed to one of the diseases which are most serious and easily carried are often quarantined, even though they have not shown any symptoms[1] of the disease.

Social implications. Quarantine should be observed in the home as much as is possible in the case of the sickness of any member of the household. The common cold would be less common if the sufferer were kept as much as possible away from other members of the family, from the time the first symptoms of the disease appear until he has recovered. Quarantine regulations are necessary for the good of the community as a whole and are observed in every requirement by all good citizens. Serious consequences are likely to result if quarantine is broken. Several years ago, during an epidemic of smallpox in a Western town, a man left the quarantined area in order to attend to some business matters in other towns. A few days later he became ill with smallpox. But before he could be quarantined, he had exposed hundreds of people to the disease. As a result of his selfish indifference to the welfare of others, many who had been exposed took the disease from him and several died.

A case is reported of a house-maid who developed smallpox. All members of the household except the maid were promptly vaccinated. But the maid, against instructions, slipped away and went to her own home. Not one of the employer's household took the disease; but three persons of the maid's family took it, and one died from it.

Self-test. 1. State six ways in which one may protect oneself from disease germs.

2. It is *usually* wise to sterilize a scratch or small wound.

3. A disease for which quarantine is required by law is (1) typhoid fever; (2) heart trouble; (3) diphtheria; (4) jaundice; (5) rheumatism; (6) cold.

4. A disease for which quarantine is desirable is (1) heart trouble; (2) tapeworm disease; (3) rheumatism; (4) jaundice; (5) trichinosis; (6) cold.

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[1] *Symptom* (sĭmp'tŭm): something which indicates the existence of a condition, as a disease.

HOW MAY THE BODY BE HELPED TO RESIST ATTACKS OF DISEASE GERMS?

How the body resists attacks from germs. *The body is constantly being attacked by germs of various kinds. It has therefore had to develop the means of defense which have enabled man to survive as an organism. The healthy body has many natural defenses against invading germs: (1) The unbroken skin and the unbroken mucous membranes afford excellent protection against the entrance of germs. (2) The secretions of the respiratory and digestive systems and of certain glands function to some extent as destroyers of germs. These are the mucus of the nose and throat, the saliva, and the digestive secretions, especially the hydrochloric acid in the gastric juice. Even tears, secreted by the tear glands, are somewhat effective in killing germs and help to protect the eyes against infection. (3)The hairs in the nose and the cilia in the passages of the lungs guard the entrance to the respiratory system to some extent. (4) An army of white corpuscles attacks the germs which manage to find their way past all these defenses into the blood. (5) Certain tissue cells also can capture bacteria from the blood in much the same way that the body cells of the sponge and *Hydra* capture food. (6) The lung cells of healthy people often build a wall around germs—for example, those of tuberculosis—which succeed in reaching the lungs, thus holding the germs helpless prisoners.

Building up immunity. Germs, when attacking the body, throw poisons, called toxins, into the blood stream. All the living cells manufacture protecting substances (antibodies). These are of several kinds. They include (1) antitoxins, which render the toxins harmless, and (2) certain substances other than antitoxins which enable the body to resist disease. Certain of these substances (agglutinins) cause the invading bacteria to gather together in masses. As a result, their harmful action is prevented or at least greatly diminished. The body manufactures one of these substances as a means of defense against typhoid. (3) Still other substances (the opsonins) act upon bacteria in such a way that the white corpuscles capture the bacteria in far greater numbers than if these substances were not present in the blood.

Natural immunity. It is a well-known fact that certain people, as well as certain animals, contract diseases more readily than others. It is known, also, that a person or an animal may contract certain diseases readily but may be immune to the attacks of other diseases to which he or it has been equally exposed. Such ability to fight off disease attacks is called natural immunity.

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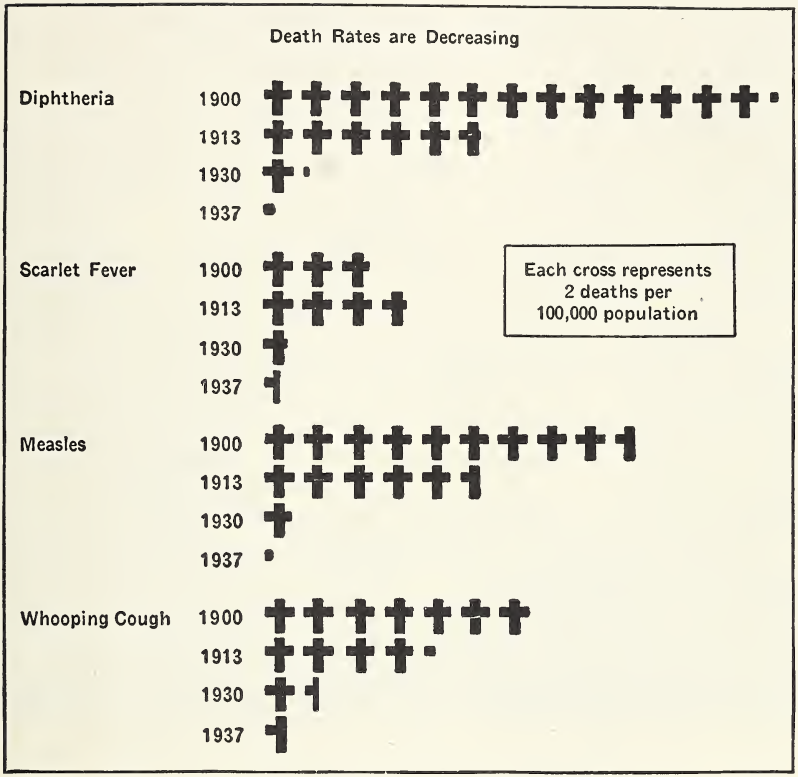
[1] *Immune* (ĭ mūn′): protected against contracting a particular disease. *Immunity* (ĭ mū′·nĭ tĭ): state of being immune. *Immunize* (ĭm′ū nīz): to make immune.



Death rates from four "children's diseases" in New York State. Explain what is meant by the term "children's diseases." What reasons can you suggest for the decrease in death rates from these diseases?

There are several kinds of natural immunity: (1) Immunity is related to a particular species. For example, man is naturally immune to many diseases of animals, as chicken cholera and Texas fever, the latter a disease of cattle. (2)Immunity is related to race. Thus the Chinese have a natural immunity to scarlet fever. This immunity is very much greater than that possessed by other races of men. The white race has a much greater natural immunity to smallpox than the American Indian. (3) Immunity is related to family. Thus the members of certain families have a much greater natural immunity to certain diseases than the members of other families. (4) Immunity is related to the individual. Thus one member of a family may readily contract mumps, scarlet fever, or other diseases, while other members of the same family may nurse the sufferer without contracting the disease. (5) Immunity is related to age. There are certain diseases, such as diphtheria, scarlet fever, and measles, which are diseases of children and are seldom contracted by adults. (6) Immunity is related to one's health. Thus, if a person is in good health, he may be exposed to a disease—for example, the common cold—many times without contracting it. If, however, he is in poor health, he may contract the disease at once when exposed to it.

Immunity acquired from having the disease. *Many of the serious bacterial diseases can be contracted only once during one's lifetime. Having these diseases renders one immune because the antitoxin and other disease-resisting substances manufactured by the body in recovering from the disease remain for a considerable time, sometimes for life. Thus one need not fear a second attack of smallpox. Also, few people contract measles or scarlet fever a second time. Other diseases give immunity for long or short periods, depending on the individual. Thus, while immunity to diphtheria for some people lasts for life, for about half the patients it lasts only a year or less. Attacks of certain diseases, such as the common cold and pneumonia, give no lasting immunity.

Foolish as it is, there are many people who welcome diseases in young children in order to secure for them the immunity which may come from having had the diseases. Thus one may hear a mother say, "I want my children to have all the children's diseases early, so that there will be no reason to fear these diseases later on." She may even purposely expose her children to measles, whooping cough, chicken pox, and other diseases.

Such practice is unscientific for three reasons: (1) It assumes that everybody is certain sooner or later to contract at least all the commoner diseases. We know that this belief is unsound because with certain diseases, such as meningitis, measles, scarlet fever, and diphtheria, natural immunity increases as one becomes older. In the outbreak of infantile paralysis in New York in 1916, more than 90 per cent of the cases were children under five years of age. These facts indicate clearly that if a person escapes these diseases as a child, he has a good chance to escape them during his entire life.

(2) It assumes that the diseases are less serious with children than with adults. We know that this belief is unsound because certain diseases which are often fatal to children are seldom fatal to adults. For example, from 90 to 95 per cent of all deaths from measles are of children under five years of age. Also, with whooping cough, the younger the child the greater the chance of death from the disease. Hospital records show that from 20 to 35 per cent of all children under one year of age who are treated in the hospitals die of the disease.

Shipvan

A modern hospital. The building is constructed so as to provide the patients with light and air. Why are these factors important?

(3) It overlooks the fact that an attack of the disease is likely to leave permanent bad effects, such as deafness, blindness, and weakened organs which are unable to resist disease.

Immunity acquired from inoculations.[1] As has been previously stated, disease germs produce poisons called toxins. These are products resulting from the life processes of germs as they feed upon the body tissues. The presence of toxins in the blood stimulates every living cell to manufacture antitoxins. These unite chemically with the toxins, rendering them harmless. If the blood contains a sufficient quantity of the antitoxin of a certain disease, the person is immune to that disease. The reason is that the toxin is made harmless by the antitoxin as soon as it enters the blood. Each antitoxin, however, can act upon only one kind of toxin. The cells must therefore manufacture a special antitoxin for every disease that attacks the body.

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[1] *Inoculate* (ĭn ŏk′ū lāt): to inject, or force, into the body some substance for the purpose of preventing or curing a disease. *Inoculation* (ĭn ŏk ū lā′shŭn): act of inoculating.

*It is probable that the blood always contains some antitoxin for every disease to which the person has been exposed. These antitoxins have been produced probably as the result of very mild attacks which the body was able to overcome. But such quantities of antitoxin as the blood may naturally contain may not be sufficient to ensure that the person will be immune. Several means have been found, however, for stimulating the cells to produce additional quantities of antitoxins. The means vary for different diseases. (1) For certain diseases, some of the toxin of the disease is introduced into the body in very small quantities or in a weakened form. (2) For others, living but weakened germs are introduced. (3) For still others, dead germs are used. In any case the body promptly manufactures antitoxins. Immunity acquired by any of these means may last from a few days to many years or in some cases as long as one lives, depending on the disease and other factors.

Medical science has also found means in the cases of several dangerous diseases, including diphtheria, smallpox, and typhoid fever, of determining whether the blood contains a sufficient quantity of antitoxins to resist attacks from these diseases. If these tests show that the quantity is not sufficient, inoculations can be given which will stimulate the cells to increase the supply of antitoxin and consequently to ensure the person's immunity.

Diseases of animals. Animals are subject to attack by many germ diseases. These diseases are treated in much the same way as those of people. For certain diseases, such as hog cholera and anthrax, serums are injected into the animal to give it immunity or to aid it in recovering from the disease. Animals with diseases such as these are quarantined to prevent the spread of the disease. Also, newly purchased animals are kept separated from other animals for a length of time sufficient to show whether or not they have contagious diseases. It is unlawful to transport an animal from some states into others unless the animal is accompanied by a certificate which states that it is free from communicable diseases.

Factors affecting immunity. A person's immunity to diseases varies from time to time for a number of reasons in addition to those previously given. For example, his immunity is certain to be less (1) if he is very tired because of either physical or mental work; (2) if he has become chilled from exposure; (3) if he has been living where there have been overcrowding, filth, and poor ventilation; (4) if he has not had enough of the right kinds of food, containing sufficient supplies of energy, building materials, and especially vitamins; and (5) if he is weakened from a recent attack of some disease. You can

United States Department of the Interior

Recreation in Rocky Mountain National Park. How do the right kinds of outdoor exercise promote good health?

therefore increase your immunity through healthful living. You should keep regular hours and have plenty of sleep, fresh air, sunshine, rest and play.

Helping the body to overcome disease attacks. Even after one has become ill, it is possible with a number of the diseases to assist the body in overcoming the attack by inoculating it with a serum containing quantities of antitoxin. These serums are usually obtained from the blood of young horses, cows, goats, or other animals which have been given mild attacks of the disease.

Summary. *Human beings are constantly open to attacks from disease parasites. We can escape some of these attacks by living under sanitary conditions and by avoiding people known to be suffering from communicable diseases. The body has a number of means of avoiding attacks. It has some means of destroying invading germs, and it has some means of combating the toxins. Immunity and the ability to recover from certain diseases can be increased by various forms of inoculations. Immunity can also be increased through healthful living. All forms of increased immunity and of increased power to recover from disease attacks come only from increasing the natural defenses of the body.

The various means of increasing immunity and of assisting the body when attacked will be illustrated more fully in the following chapter, which deals with specific diseases.

Self-test. **1.** Name six defenses of the body against disease.

2. Name six factors upon which natural immunity depends.

3. Select from the following words or phrases the one which does not belong with the rest: (1) mucus; (2) cilia; (3) tears; (4) gastric juices; (5) white corpuscles; (6) whole skin; (7) urea.

4. State three reasons why it is wise not to expose children to the common diseases while they are young.

5. Name five conditions which may determine whether or not one will become ill of communicable diseases.

6. A substance manufactured by protoplasm to counteract a poison produced by a disease is an --?--.

Self-test on Important Biological Terms

antitoxin
communicable disease
disinfectant
germ
germicide
immunity
inoculation
toxin

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Which conditions favorable to the growth of bacteria occur in the human body?

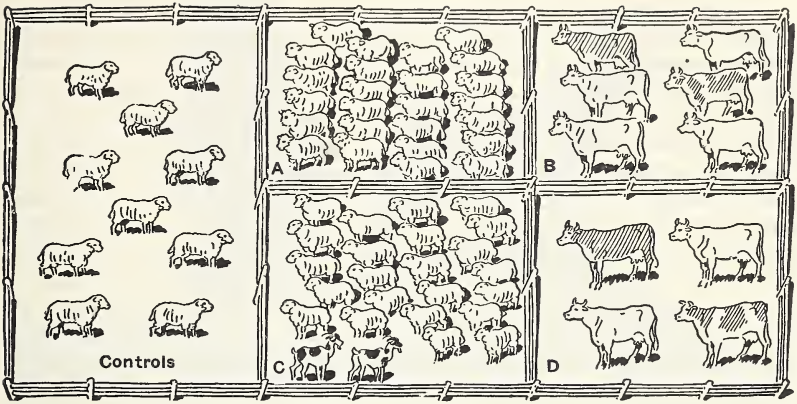
2. Why should you avoid crowded unventilated rooms as much as possible?

3. Typhoid has been known in some cases to be contracted from eating raw oysters. Can you explain how the oysters might have become contaminated?

4. How many ways can you list in which food and drinking water may be protected from contamination?

5. Why is it better never to have had such diseases as scarlet fever, whooping cough, and diphtheria?

Exercises on Scientific Method. 1. *Evaluating Experiments.* Louis Pasteur (1822–1895), a famous French chemist and biologist, made more important scientific discoveries which contribute to human welfare than any other scientist in the world's history. He began his scientific investigations as a chemist but made his chief repu-



Challenged by the Agricultural Society of Melun, France, Pasteur and his assistants prepared a demonstration which is illustrated by this diagram. Delegates were invited from several countries. On May 5, 1881, a first vaccination was given to twenty-five sheep and six cows (A and B). In near-by pens were twenty-three sheep, two goats, and four cows, none of which were vaccinated (C and D). On May 17 a second vaccination was given to the twenty-five sheep and six cows. On May 31 all except ten controls were given active anthrax germs. The delegates were told to return on the morning of June 2. On that day all non-vaccinated sheep, the two goats, and the four cows were sick or dead. *No vaccinated sheep, cows,* or *controls* were sick. What elements of scientific method were used in this demonstration?

tation as a scientist who studies bacteria (a bacteriologist). His earliest experiments, which were upon the causes of fermentation, were of immense value to the wine and beer industries. In connection with these experiments, he produced evidence which was important in the overthrow of the "theory of spontaneous generation." Later he found the cause and suggested a cure for the silkworm disease, which had nearly ruined the silk industry in France and Italy. He is most famous, however, for his discovery of the method of curing disease by inoculating a patient with a weakened culture of the bacteria that cause the disease. Experimenting first with diseases of animals, such as chicken cholera and anthrax, he extended his treatment to human beings. He is most famous for discovering a cure for hydrophobia.

From encyclopedias and biographies find and list the scientific methods which Pasteur followed in his work. What native qualities did he possess which made him a successful investigator? What is the story of his study of wine fermentation? of the silkworm disease? What is the story of the boy Jufille and Pasteur's successful attempt to cure him of hydrophobia?

2. *Making Hypotheses.* Adult city dwellers have a greater natural immunity to scarlet fever than adult country dwellers. How many possible reasons (hypotheses) can you state which might account for this fact?

3. *Applications of Methods to New Situations.* Robert Koch (1843–1910), a German scientist, is famous for his investigations of diseases caused by bacteria. His first notable work was upon anthrax. Later he discovered the germs of tuberculosis and Asiatic cholera. He also made notable studies of bubonic plague, sleeping sickness, and malaria. In 1882 he invented the method still used for investigating the cause of a disease. Koch's method consists of four steps: (1) examine the blood and tissues of the diseased animal or person until some organism is found which is not found in normal tissues; (2) make a pure culture of this organism; (3) introduce some of the germs from this culture into the blood or tissues of a normal animal, and observe the animal to note whether it becomes sick of the disease; (4) examine the blood or tissues of this diseased animal to see whether the suspected organism is present in them. If it is present, one may be reasonably certain that the organism was the cause of the disease.

What is the story of tuberculin? Do Koch's four steps provide for controls? Explain.

Exercise on Scientific Attitudes. 1. Joseph Lister (1827–1912), an English surgeon, introduced modern practices in the treatment of open wounds. Appalled by the high percentage of patients who died from infections following surgical operations and from wounds of all sorts in which the skin was broken, he carried on long and patient investigations to find ways of ensuring normal healing. Building upon two facts which had been established largely through the work of Pasteur,—namely, that all decay of organic matter is due to living organisms and that microscopic organisms are produced by organisms like themselves,—he decided that infection could be prevented by keeping the wound, the operating instruments, and the bandages free from living bacteria. Lister's experiments have had a powerful influence upon modern surgical practice.

What investigations led Lister to give up the idea that wounds are infected by the air? (Consult an encyclopedia or a history of science.) What scientific attitudes (p. 624) are illustrated by Lister's work?

2. Which of the scientific attitudes is implied in this statement: "A few years ago nobody had heard of filtrable viruses"?

Special Reports. 1. Lister's surgical practice put more emphasis upon antiseptic surgery than upon aseptic surgery. Modern surgery stresses aseptic practice. What is the distinction between antiseptic and aseptic surgery? Consult an encyclopedia or your family physician for facts.

2. Secure from your family physician a list of noncommunicable diseases other than those mentioned here.

3. What is the story of "Typhoid Mary"?

4. What kinds of vaccinations were given to the men and women of our armed forces who were going into service in foreign countries?

Gunnar Kasson, Balto, and Balto's statue in Central Park, New York City

HOW THE ANTITOXIN WAS BROUGHT TO NOME

Early in 1925 Nome, Alaska, was stricken with diphtheria. The limited supply of antitoxin serum was exhausted almost at once. Without more, the city faced a desperate situation. The nearest railroad point was Nenana, six hundred fifty-five miles away. The ice prevented boats from reaching Nome. Airplanes tried to reach the city but failed. Serum could be brought only by relays of dog teams over the snow, ice, and the frozen shores of Bering Sea. Experienced and skillful drivers and relay teams of the best dogs were chosen, and the fearful day-and-night race was started against disease and death.

Five drivers in turn took the precious serum the first five hundred miles. Seppala, the next driver, was warned not to cut across Norton Sound because the ice was already breaking up and drifting to sea. But because the safer route around Norton Bay would require two more days, Seppala, guided by his gallant lead dog Togo, boldly crossed the dangerous heaving ice.

When the package reached Gunnar Kasson at Bluff, a blizzard had developed so fierce that the most experienced "mushers" believed it impossible for man and dogs to face it or to keep the trail. But Kasson started, at times scarcely able to see his nearest dog. He became lost, as did also his lead dog. He then put Balto, his alternate lead dog, in the lead and ordered him to "go home." Despite the eighty-mile gale Balto kept steadily on over snowdrifts, bare frozen ground, and the glare ice of the lagoons. Kasson reached Nome in the early morning, February 2, 1925, himself and his dogs half frozen. The nine-day trip had been made by the eight drivers in five and a half days!

Because of their heroic parts in this race, Balto and his five teammates were given a home in Brookside Park, Cleveland, where Balto died in 1933.

CHAPTER XXV

How Science Combats Certain Germ Diseases

Questions This Chapter Answers. 1. Can disease be controlled? · 2. What are the various methods used by science in combating diphtheria? · 3. What means are used in fighting smallpox? · 4. How can typhoid be controlled? · 5. How is the danger from tuberculosis being reduced? · 6. What progress is being made in combating malaria and yellow fever?

HOW DOES SCIENCE COMBAT DIPHTHERIA, SMALLPOX, AND TYPHOID?

Early medical practices. Unscientific practices have always accompanied the treatment of disease. Charms to prevent and to cure sickness have been common throughout history. Even occasionally today a bag of asafetida is worn around the neck to prevent scarlet fever, a horse-chestnut is carried in the pocket to cure rheumatism, an amber necklace is worn to cure goiter, and so on. A few centuries ago even stranger things were used as remedies. Medicines compounded for wealthy patients contained such astonishing substances as bits of Egyptian mummy, though, as some of the doctors complained, much of the mummy used was "made in France"; unicorn's horn, which was usually a bit of ivory; or a "bezoar" which was most frequently a gallstone taken from a goat or a hair-ball taken from a cow's stomach. All these remarkable "drugs" were very expensive. A single piece of "unicorn's horn," for example, once sold for the equivalent of $75,000. Remedies, especially those for poorer patients, were likely to contain such "drugs" as crushed insects and burned toads.

Several centuries ago it was not unusual for a doctor to prescribe a remedy which contained more than a hundred different substances. The difficulty in getting such "medicines" prepared can be realized from the fact that there were then no drug-stores. In fact, the first drug-stores were grocery stores in which drugs and doctors' supplies were sold as a side line.

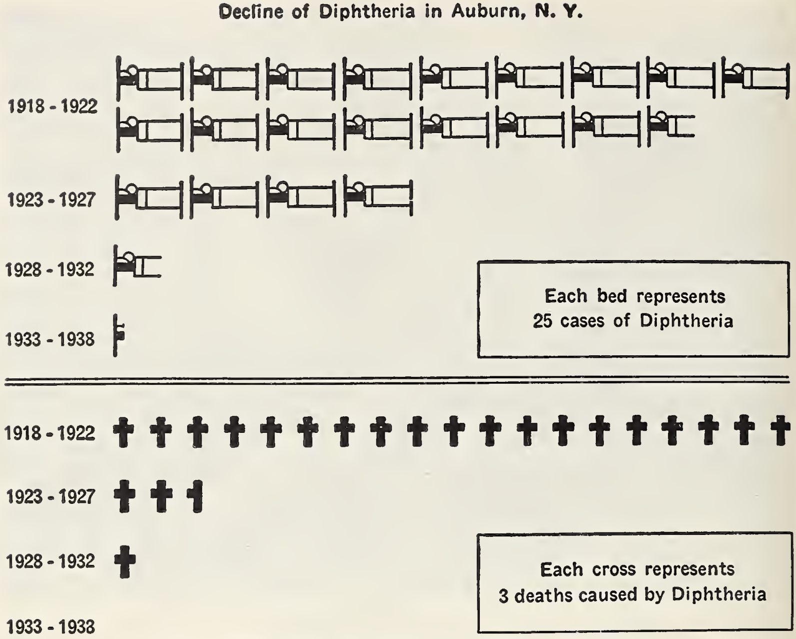
Progress in reducing disease. From early times special efforts have been made to combat certain diseases which are regarded with unusual dread. Included among these diseases are diphtheria, smallpox, typhoid, tuberculosis, malaria, and yellow fever. During the years that have passed since they were first definitely recognized, so that records could be kept of them, each has been responsible for a serious amount of sickness and death. They are still formidable. But medical science has been improving its means of defense. Such great progress has recently been made in reducing the sick rate and the death rate from these and other diseases as to justify the hope that if the program of prevention and treatment outlined by the scientists is intelligently followed, these diseases can be practically eliminated in a relatively short time.

How do the modern methods of preventing disease differ from those in which this Indian medicine man believed?

Diphtheria. *The progress in the fight against diphtheria has been accomplished through three medical triumphs: (1) the use of antitoxin, (2) the perfecting of a test of immunity, and (3) the use of toxoid or toxin-antitoxin in producing immunity.

The use of antitoxin in the treatment of diphtheria became general in 1894. Before that time from 30 to 50 per cent of all who contracted diphtheria died. At present, through the use of antitoxin, the disease is fatal to only 6 to 8 per cent. The person who has contracted diphtheria can in most cases be cured by injections of the antitoxin, usually into a muscle or in severe cases into both a muscle and a vein. It is important that the treatment be begun as early as possible, since the antitoxin has less effect the longer the disease has run. The reason is that the antitoxin makes the toxin harmless as it is produced by the bacteria. But if the toxin has had an opportunity to combine with various tissues, especially those of the heart, then the antitoxin cannot repair the damage already done. It can, however, prevent further damage.

The antitoxin is prepared from horse serum. Diphtheria toxin in gradually increasing but harmless amounts is injected into a healthy young horse.



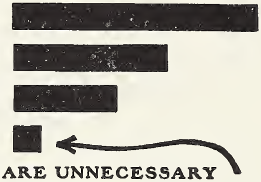
Results of the diphtheria-prevention campaign in Auburn, New York. Each bed represents 25 cases of diphtheria. Each cross represents 3 deaths caused by diphtheria. **Exercise on Scientific Attitudes:** Which of the scientific attitudes (p. 624) does the person have who believes from this evidence that diphtheria prevention pays?

The cells of the horse immediately begin to manufacture antitoxin to render the toxin harmless. Later the blood containing the antitoxin is drawn from the horse without injury to the animal. The clot containing the blood corpuscles is removed, leaving the clear serum containing the antitoxin. Some of this serum mixed with toxin is injected into a healthy guinea pig. If the guinea pig lives, the serum is considered ready for use with human beings.

In 1913 the Schick test was introduced. By means of this test it is possible to determine whether a person is immune to diphtheria. A small dose of the diphtheria toxin is injected beneath the skin. If the patient is immune, nothing happens, because the antitoxin in the blood quickly counteracts, or overcomes, the effects of the poison. But if the patient is not immune, a red spot develops at the point where the toxin was injected. Such a person can then be made immune for several years or perhaps even for life by being inoculated with either toxoid or toxin-antitoxin.

CHILD HEALTH WEEK

HOW ANTI-TOXIN AND TOXIN-ANTI-TOXIN HAVE CONQUERED DIPHTHERIA IN NEW YORK CITY



- Thirty Years Ago More Than 2000 Children Died Each Year from Diphtheria
- Twenty Years Ago More Than 1200 Children Died Each Year from Diphtheria
- Ten Years Ago Almost Nine Hundred Children Died Each Year from Diphtheria
- Last Year 212 Children Died from Diphtheria

EVEN THESE DEATHS ARE UNNECESSARY

Let Us Wipe Out Diphtheria As We Have Wiped Out Small-pox!

ASK YOUR DOCTOR HOW TO BE PROTECTED AGAINST THIS DISEASE, OR WRITE TO YOUR DEPARTMENT OF HEALTH

This information was placed in electric cars by the department of public health of New York City, in the spring of 1933. In 1937 there were 57 deaths from diphtheria in New York City. Is the decrease in the number of deaths from diphtheria greater or less between 1923 and 1932 than between 1932 and 1937?

Toxoid is made of a diphtheria toxin which has been weakened by being mixed with formaldehyde and kept for a week at a certain temperature. Toxin-antitoxin is made by mixing diphtheria toxin with almost enough antitoxin to make it harmless. Either the toxoid or the toxin-antitoxin is injected beneath the skin. One inoculation with toxoid is enough; but the inoculation with toxin-antitoxin is repeated from three to five times, at intervals of a week, until the Schick test shows the person to be immune.

The toxoid method is now rapidly taking the place of the toxin-antitoxin method because (1) it makes a greater percentage of people immune to diphtheria, (2) it needs to be injected only once instead of many times, and (3) its use is not followed by a disturbance of the child's health, as is sometimes the case with injections of toxin-antitoxin.

Since it is young children who are most likely to contract diphtheria, the immunity treatment should be given before a child goes to school. The best age is from six to eighteen months. Children with diseased tonsils are especially likely to contract diphtheria.

Smallpox. It is claimed that smallpox was known in China a thousand years before Christ. From that time until vaccination became a common practice, smallpox was probably the most feared and dreaded of all diseases.

Smallpox is said to have been introduced into America by a Negro slave who accompanied the Spanish conqueror Cortes to Mexico in 1519. Sweeping

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Exercise on Scientific Attitudes: When Jenner first began to vaccinate against smallpox, it was known that vaccine was secured from cows. Some people feared that if they were vaccinated, cows' heads would grow all over their bodies. Which of the scientific attitudes would make one refuse to accept this belief?

over the country, it found easy victims among the Indians, sometimes killing every member of a tribe. It is stated that as late as 1750, in certain countries of Europe, half the people contracted smallpox during their lives, one tenth died, and one tenth were disfigured for life. Now, in those states and countries in which vaccination is compulsory,[1] the danger from smallpox has been so greatly reduced that it is no longer considered to be one of the most deadly diseases.

Cattle which have contracted cowpox, a disease of cattle similar to smallpox and possibly identical with it, have from the earliest days of vaccination served as the chief source of the vaccine, or virus.[2] Often, however, even in fairly recent times, the virus was obtained from people. In this way other

[1] *Compulsory* (kŏm pŭl'sō rĭ): required by law; not avoidable.

[2] *Virus* (vī'rŭs): a poison capable of transmitting a disease.

diseases—for example, tetanus—were transmitted along with the smallpox virus. The name *virus* was used in connection with smallpox many years before filtrable viruses were known. Strange as it seems, it is now thought that the disease is caused by a filtrable virus and not by bacteria or protozoans.

The vaccine is now secured from young calves. A portion of the belly is inoculated with the virus. After five days the "pocks" have developed all over the inoculated area. The calf is then killed, and the virus from the pocks is drained into containers which have been thoroughly sterilized. A mixture of 50 per cent glycerin, 49 per cent water, and 1 per cent carbolic acid is now added to the virus. The glycerin and carbolic acid kill any live organisms. After the mixture has stood for four weeks, it is carefully tested to make certain that it contains no harmful organisms. It is now ready for use as a vaccine.

*Vaccination consists in introducing a little of the serum, or vaccine, into a scratch in the skin. If the person is not immune to smallpox, a single pock forms at the point where the vaccine was introduced. This pock goes through various changes until after about eighteen days the scab, or crust, comes off, leaving a scar.

*Vaccination gives immunity in nearly every case. This immunity usually lasts about six years and may last much longer. If the vaccination is then repeated, the immunity is likely to last for life. Vaccination even after one has been exposed to smallpox has been found of benefit in making the disease less severe. Whether one has been successfully vaccinated or not, one should be vaccinated again in the event of an outbreak of the disease or before going to foreign countries.

Scientific evidence shows beyond doubt the value of vaccination. In Sweden the death rate for smallpox was decreased from 2050 per million inhabitants before vaccination to only 158 per million after vaccination. In the United States there is no national compulsory vaccination law. Six states have no vaccination laws whatever, and in only fourteen are the children compelled to be vaccinated before they are allowed to attend school. A comparison of the number of cases of smallpox in states having compulsory vaccination laws with those in states having no such laws should convince everybody of the great value of vaccination.

Typhoid. Immunity to typhoid may be secured through vaccination similar to that for smallpox. The vaccine for typhoid, however, consists of the dead bodies of the typhoid germs. The germs are grown in an agar culture. They are then killed by heat. A small quantity of carbolic acid added to the vaccine preserves it. The vaccine is administered three times, with intervals of one week between inoculations. The immunity thus secured usually lasts from a few months to about two and a half years.

The value of typhoid inoculation was clearly proved during the World War. There were almost no cases of typhoid in the United States army, because all the men were given typhoid vaccine. Similar results were secured in the British and French armies. In the Spanish-American War, however, before typhoid vaccines were available, more than one fifth of the soldiers contracted the disease.

A test (Widal's test) has been developed which, before the disease has become sufficiently advanced to be easily recognized, indicates whether one has it or not. Several drops of blood of the person suspected are allowed to stand until the serum separates. This serum is made less strong by adding a weak solution of salt. Living typhoid bacteria are then added. If the disease has already become active in the system, the typhoid bacteria will immediately gather in groups. Such groups indicate that the body has already begun to manufacture the particular substance which is needed as a defense against this particular disease.

Self-test. 1. People can usually be cured of diphtheria by injections of (1) toxin; (2) antitoxin; (3) cow serum; (4) vaccine; (5) toxin-antitoxin; (6) weakened toxin.

2. People can usually be rendered immune to diphtheria by injections of (1) toxin; (2) antitoxin; (3) cow serum; (4) vaccine; (5) toxoid; (6) blood.

3. It is usually possible to determine whether a person is immune to diphtheria by the use of the --?-- test.

4. People can usually be rendered immune to --?-- by means of vaccination with virus secured from young calves.

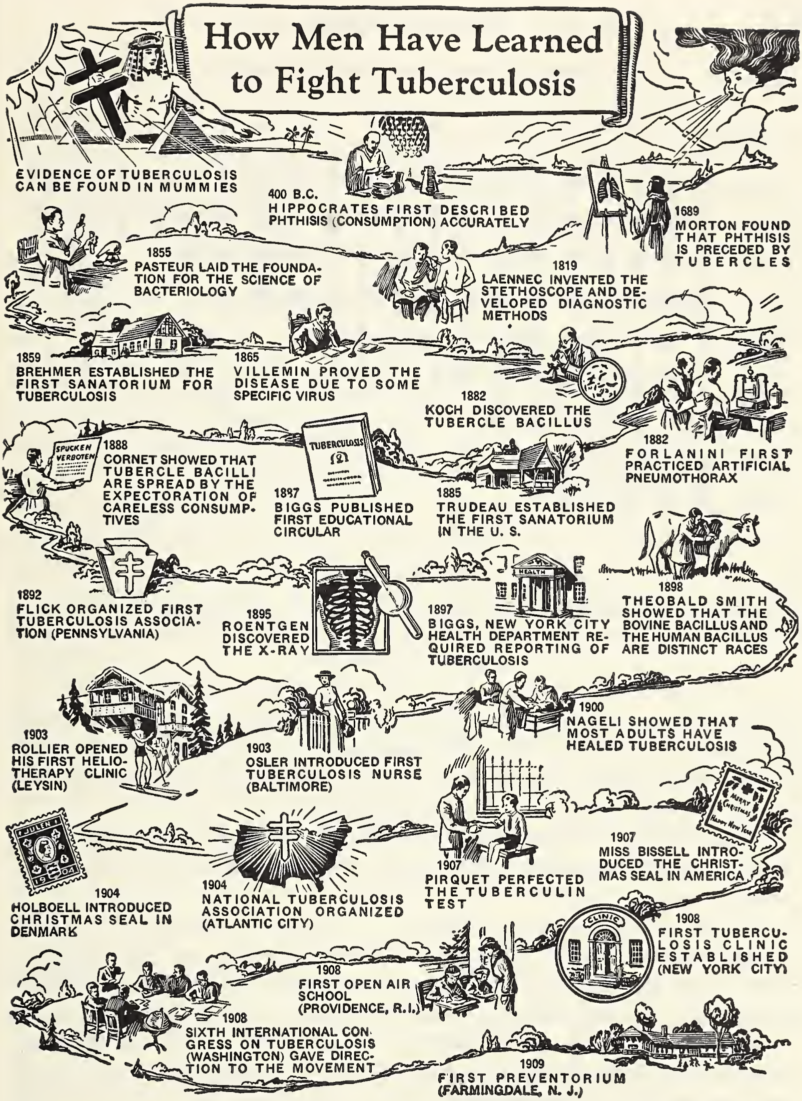
5. A disease to which immunity is usually obtained by vaccination with dead bacteria of the disease is (1) smallpox; (2) typhoid; (3) tuberculosis; (4) scarlet fever; (5) measles; (6) trichinosis.

HOW DOES SCIENCE COMBAT TUBERCULOSIS?

Tuberculosis. In the beginning of this century tuberculosis was responsible for more deaths in the United States than any other single disease. Because it was so common and so deadly it was known as "the great white plague." During the past quarter-century its death rate has been steadily declining. It now has seventh place among deadly diseases in the United States. Yet there were a million and a half cases from which there were about seventy thousand deaths in 1938.

Tuberculosis may attack any organ of the body; but it is especially likely to attack the lungs, the glands of the neck, the kidneys, or the bones and joints. People become infected with it usually during childhood. Tuber-

How Men Have Learned to Fight Tuberculosis



EVIDENCE OF TUBERCULOSIS CAN BE FOUND IN MUMMIES

400 B.C.
HIPPOCRATES FIRST DESCRIBED PHTHISIS (CONSUMPTION) ACCURATELY

1689
MORTON FOUND THAT PHTHISIS IS PRECEDED BY TUBERCLES

1855
PASTEUR LAID THE FOUNDATION FOR THE SCIENCE OF BACTERIOLOGY

1819
LAENNEC INVENTED THE STETHOSCOPE AND DEVELOPED DIAGNOSTIC METHODS

1859
BREHMER ESTABLISHED THE FIRST SANATORIUM FOR TUBERCULOSIS

1865
VILLEMIN PROVED THE DISEASE DUE TO SOME SPECIFIC VIRUS

1882
KOCH DISCOVERED THE TUBERCLE BACILLUS

1882
FORLANINI FIRST PRACTICED ARTIFICIAL PNEUMOTHORAX

1888
CORNET SHOWED THAT TUBERCLE BACILLI ARE SPREAD BY THE EXPECTORATION OF CARELESS CONSUMPTIVES

1887
BIGGS PUBLISHED FIRST EDUCATIONAL CIRCULAR

1885
TRUDEAU ESTABLISHED THE FIRST SANATORIUM IN THE U. S.

1892
FLICK ORGANIZED FIRST TUBERCULOSIS ASSOCIATION (PENNSYLVANIA)

1895
ROENTGEN DISCOVERED THE X-RAY

1897
BIGGS, NEW YORK CITY HEALTH DEPARTMENT REQUIRED REPORTING OF TUBERCULOSIS

1898
THEOBALD SMITH SHOWED THAT THE BOVINE BACILLUS AND THE HUMAN BACILLUS ARE DISTINCT RACES

1903
ROLLIER OPENED HIS FIRST HELIOTHERAPY CLINIC (LEYSIN)

1903
OSLER INTRODUCED FIRST TUBERCULOSIS NURSE (BALTIMORE)

1900
NAGELI SHOWED THAT MOST ADULTS HAVE HEALED TUBERCULOSIS

1904
HOLBOELL INTRODUCED CHRISTMAS SEAL IN DENMARK

1904
NATIONAL TUBERCULOSIS ASSOCIATION ORGANIZED (ATLANTIC CITY)

1907
PIRQUET PERFECTED THE TUBERCULIN TEST

1907
MISS BISSELL INTRODUCED THE CHRISTMAS SEAL IN AMERICA

1908
FIRST TUBERCULOSIS CLINIC ESTABLISHED (NEW YORK CITY)

1908
FIRST OPEN AIR SCHOOL (PROVIDENCE, R.I.)

1908
SIXTH INTERNATIONAL CONGRESS ON TUBERCULOSIS (WASHINGTON) GAVE DIRECTION TO THE MOVEMENT

1909
FIRST PREVENTORIUM (FARMINGDALE, N. J.)

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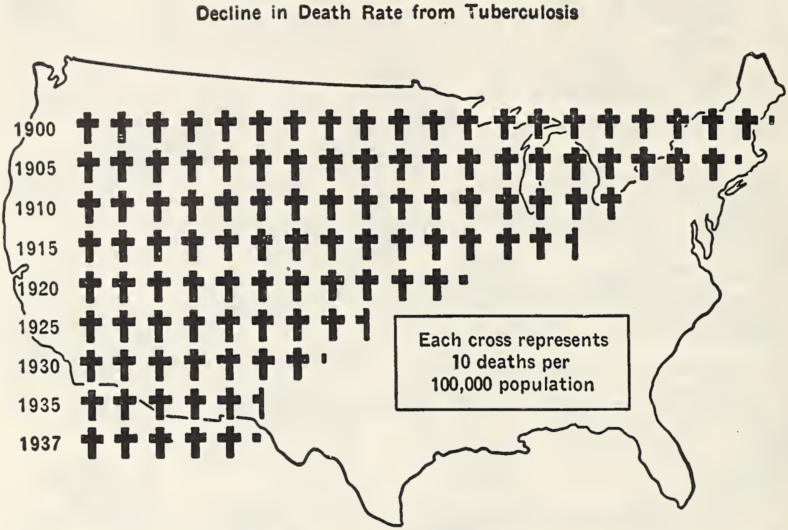
THE DEATH RATE IS STEADILY DECLINING

Can you name three scientific inventions which were especially important in the fight against tuberculosis?


Decline in Death Rate from Tuberculosis

The decline of tuberculosis in the United States. Forty years ago the death rate from tuberculosis was about four times what it is now. Can you select facts from this figure to prove this statement?

culosis may remain latent, that is, dormant, for many years or even for life, provided the resistance of the body is maintained at a high level. Later the disease may become active if one's resistance is broken down, or if the one having the infection is strongly infected again.

*Tuberculosis is not inherited. The children of parents who have tuberculosis, however, may contract it directly from the diseased (or tuberculous) parents.

People contract tuberculosis chiefly (1) by eating food upon which the living bacteria from the discharges of tuberculous patients have settled or upon which flies carrying the bacteria have lighted; (2) by drinking milk or eating butter from cows which have the disease; (3) by handling objects which persons ill with tuberculosis have handled. Tuberculosis is also transmitted (4) by germs in the air, in the dust on the streets or floors, or on doors or furnishings of public buildings. People who spend much of their time out of doors are less liable to the disease than those who live mostly indoors.

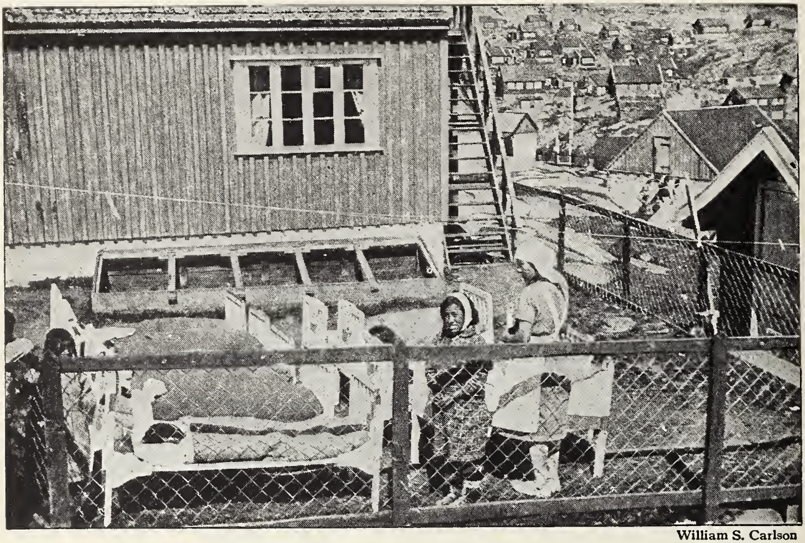
The form of tuberculosis which is spread by milk from cows having the disease is especially dangerous to children. This form attacks the lymph glands and the bones, but rarely attacks the lungs. The development of pioneer work by Koch has resulted in tests which can be applied to cattle to determine whether they are suffering from tuberculosis or have had the disease. In many states of the United States the killing of all animals which as a result of this test are proved to have tuberculosis is required by law. In some states part of the value of these animals is paid to the farmer by the state. As a result of this careful testing program, there are today more than three hundred thousand herds of milk cows known to be free from tuberculosis.

Recently a method of vaccination of cattle has been introduced which gives promise of eliminating the danger from tuberculosis in cows. Calves are vaccinated before they are fifteen days old and again once every year. Although not enough cattle have yet been vaccinated in this way to make the value of such vaccination certain, nevertheless the favorable results already secured encourage the hope that cattle thus treated are rendered immune.

Scientists in many countries are working to develop a vaccine to make human beings immune to tuberculosis. The most successful vaccine (BCG) contains living bacteria which have been weakened so that they cannot produce the disease. Thus far, however, the results have not been certain, though it is believed that babies have gained some protection from the vaccination. A test similar to the Schick test for diphtheria has been developed also for tuberculosis.

*It was formerly thought that there was no cure for tuberculosis. Now it is known that if the proper treatment is begun during the earlier stages of the disease, there is a very good chance of recovery. The patient should have (1) complete rest, (2) plenty of fresh air, (3) plenty of sleep, ten hours at first—later eight, (4) abundant sunshine, but not too much exposure to intense sunshine, and (5) a well-balanced diet with a plentiful supply of vitamins. These all help to build up the bodily resistance, so that the bacteria can do no harm. In certain types of tuberculosis, surgical treatment is being employed with successful results.

Now that the nature of tuberculosis and the ways in which it may be spread are known, much can be done toward preventing its spread: (1) One can protect oneself to a considerable extent by keeping the body resistance high through observing the rules for healthful living. (2) One can have a thorough physical examination every year, supplemented by X-ray photographs of the lungs, so that the disease, if present, can be detected in its earlier stages. (3) All patients suffering from active tuberculosis should be treated in hospitals. (4) The patient suffering from the disease should protect others by covering his mouth and nose with cotton gauze or paper gauze when coughing or sneezing, and by then burning these cloths or



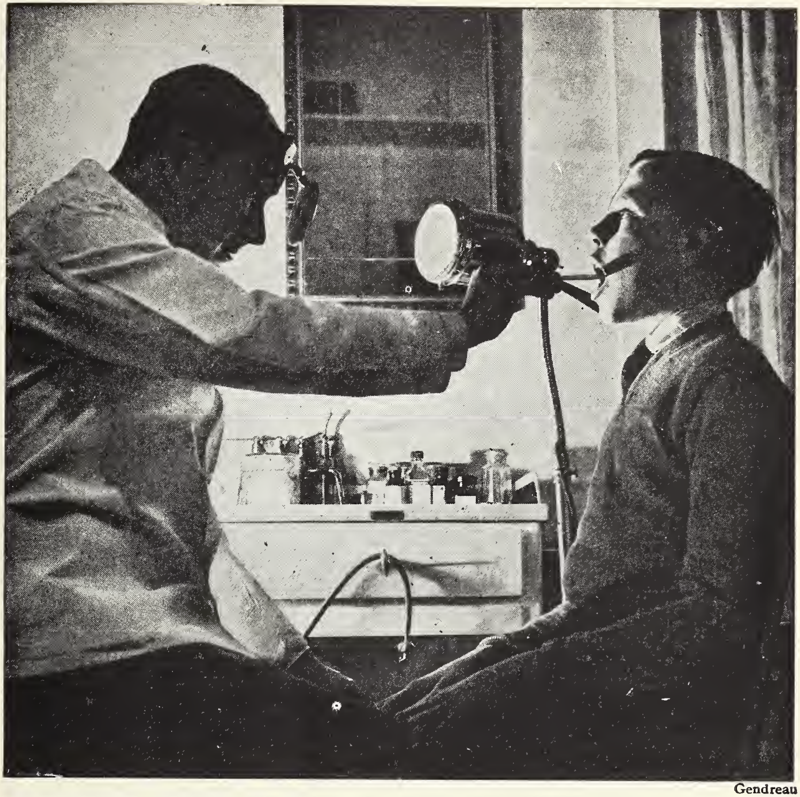
William S. Carlson

An Eskimo tuberculosis hospital in Greenland. How many of the conditions necessary for the treatment of tuberculosis are evident here?

papers. He should also collect in special receptacles and burn all material eliminated by coughing. (5) Families may protect themselves by buying milk which is from cows known to be free from tuberculosis, or which has been pasteurized, and by buying food which is protected from flies and dust.

Summary. *Diphtheria, smallpox, typhoid, and tuberculosis are known to result from the attacks of certain parasitic organisms, which secrete poisons and excrete them into the blood. These diseases and many others are contracted through more or less direct contact with those suffering from the diseases or through food, water, and milk which contain bacteria from diseased persons or animals. Science has discovered ways of stimulating the body to increase its resistance to various diseases. These artificial means include inoculation (1) with antitoxins, (2) with dead bacteria, (3) with weakened bacteria, (4) with weakened toxins, and (5) with a mixture of a toxin and its antitoxin. By such means as these not only can practically complete immunity be had to such diseases as smallpox, typhoid, and diphtheria, but also the chances of recovery of people suffering from certain diseases can be greatly increased.

The number of cases and the death rate are steadily decreasing for most of the deadly bacterial diseases. This improvement has been brought about



Gendreau

What are the advantages of having a thorough physical examination annually?

through (1) better sanitation, (2) more complete knowledge of the nature of the diseases, (3) better care of patients, (4) wider use of methods of prevention, and (5) wider use of inoculation. These diseases can be all but eliminated if people will pass and enforce laws which physicians and boards of health advise as necessary.

New advances in medicine. Recent discoveries may change completely some of the present methods of disease prevention. A certain chemical (sulfanilamide) and other related chemicals have proved very successful in treating a number of infections, as septic sore throat, scarlet fever, erysipelas, and some kinds of pneumonia. These drugs aid the body in its fight against some especially deadly germs (as streptococci). Another discovery, which thus far has been tried only on animals, is that certain chemicals will cause the body to produce substances which will give immunity to such a disease as pneumonia. Perhaps in the future chemical vaccines will successfully combat many diseases.

Self-test. 1. Less than fifty years ago tuberculosis was the *most* deadly of all diseases.

2. *Tuberculosis* may attack any one of several organs or parts of the body.

3. *Some* people are born with tuberculosis.

4. State four ways in which tuberculosis is spread.

5. Tuberculosis is usually contracted when one is *an adult.*

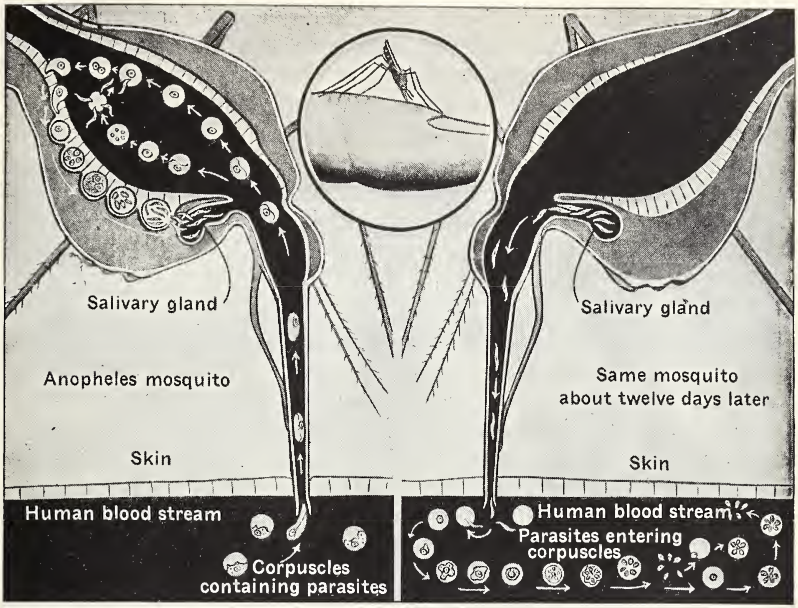
HOW DOES SCIENCE COMBAT SOME OF THE MOST SERIOUS DISEASES CAUSED BY PROTOZOA?

Diseases caused by Protozoa. Among the most deadly diseases are some which are due, not to bacteria, but to Protozoa. Malaria has been a scourge to mankind for hundreds of years. African sleeping sickness is caused by a protozoan which is carried by the tsetse fly. Amoebic dysentery is caused by a species of *Amoeba* living in the intestine. It is a serious problem in certain parts of the Southern states. It was a constant and serious danger to our armed forces in Africa especially and in the South Pacific.

Malaria. Malaria of several forms occurs in many parts of the world. Malaria was one of the greatest dangers to our armed forces in the islands of the South Pacific and in Africa during the Second World War. It is estimated that in India alone malaria is responsible for more than a million deaths per year. Of the European countries Italy especially has suffered. In the South and Middle West in the United States malaria has been a serious disease for the past fifty or more years.

The name *malaria* comes from two Italian words meaning "bad air." The disease got this name because it was thought to be caused by swamp air. In the United States it has gone under various names, such as "ague," "fever and ague," and "chills and fever." It is now known to be caused by a protozoan. During part of its life this protozoan is a parasite in a certain genus of mosquito (*Anopheles*). During the rest of its life it is a parasite in human beings or some of the other higher animals. The malarial parasite can live in only one kind of mosquito.

If a mosquito of this genus sucks the blood of a person or an animal sick with malaria, it draws into its digestive system some of the parasites. In the mosquito's body they undergo several changes. Male and female cells join


Salivary gland
Anopheles mosquito
Skin
Human blood stream
Corpuscles containing parasites
Salivary gland
Same mosquito about twelve days later
Skin
Human blood stream
Parasites entering corpuscles

The life history of the malarial parasite. Can you explain these diagrams? Only the female mosquitoes bite. If the adult males eat at all, they feed only on plant juices

in the mosquito's stomach, forming new cells. These bore into the stomach walls and form cysts. After undergoing further changes, these cysts divide into thousands of spores. These escape from the cysts and enter the blood stream, which carries them to all parts of the mosquito's body. They infect the salivary glands especially. About twelve days are required for all these changes to take place in the body of the mosquito. The parasites are now ready to complete their life cycle in the body of man or in the bodies of certain other animals.

When the mosquito bites a man, a horse, or a cow, the spores are transferred to the blood stream of the new host. They enter some of the red corpuscles of the blood, upon which they feed. There they undergo changes, as a result of which from six to sixteen spores are formed for each original spore. The time required for these changes is twenty-four, forty-eight, or seventy-two hours, depending on which type of malaria the mosquito carried.

The spores destroy the red corpuscles in which they were formed. With their poisons they are then scattered through the blood stream. Each now enters a new red corpuscle. Some develop into the male and female cells which, when taken into a mosquito's body, undergo the changes already described. The rest multiply rapidly in the corpuscles as before, releasing other multitudes of spores. They may destroy more than half the red corpuscles, thus causing anemia. The chills and fever are believed to result from the sudden addition of toxin to the blood stream when the vast numbers of spores escape at the same time from the corpuscles into the blood.

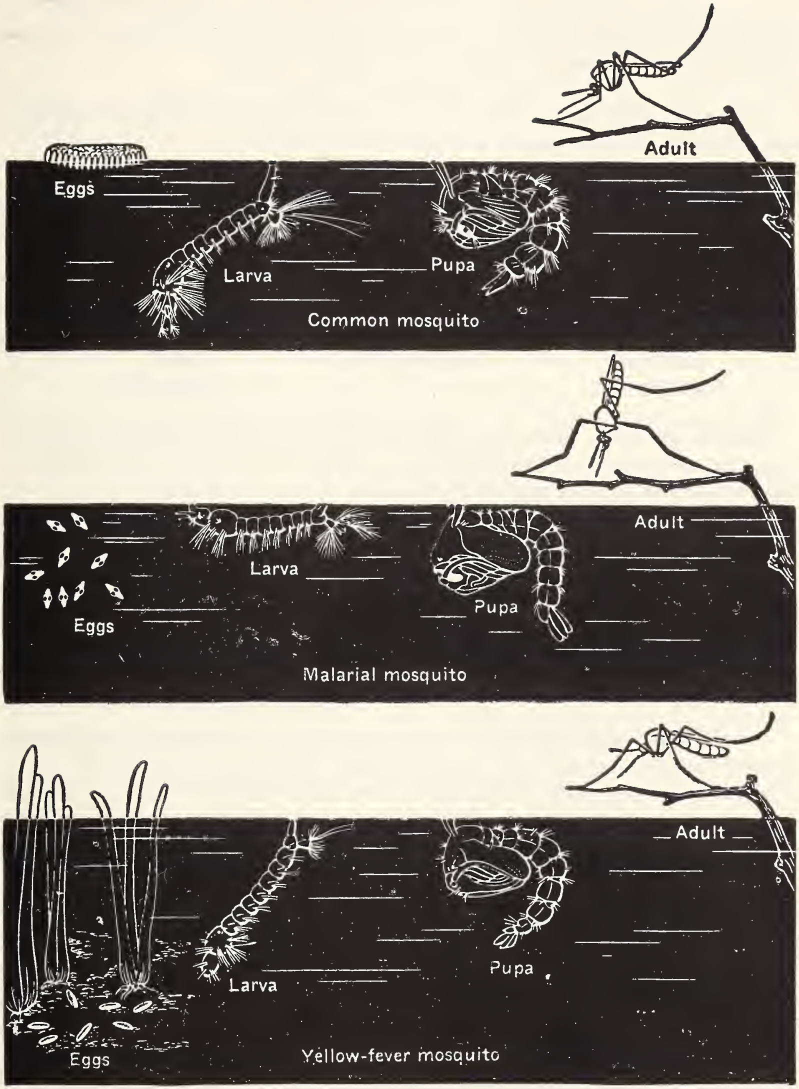
Quinine is a cure for malaria. It also prevents the disease to some extent, since it kills the parasites in the blood. However, malaria can be prevented more effectively in other ways: (1) People should be protected with screens, so that no mosquitoes can reach them. Since these mosquitoes feed mostly at night, people should be especially careful, in regions where there is malaria, to keep within screened houses during the night. (2) The breeding places of the mosquitoes should if possible be drained. Cisterns should be screened. (3) Oil or other substances which kill the larvae should be poured upon puddles and swamps which cannot be drained. (4) Goldfish and other "top feeders," especially the gambusia of North Carolina, eat the larvae and pupae. So valuable is the gambusia for this purpose that a few years ago these fish were transported to certain swamps in sections of Greece and Italy where malaria was especially prevalent. (5) It has been found also that the presence of cattle and horses serves as a protection to human beings because the mosquitoes prefer their blood to that of man.

Malaria is still a common and serious disease; yet through the use of the methods described in the preceding paragraph it is far less frequent now than formerly. In fact, in Rome, in Havana, and in the Panama Canal Zone, as well as in the Middle West and other parts of the United States, the number of cases has been reduced to a small fraction of the number thirty years ago.

Yellow fever. Yellow fever is a disease caused by a parasite, possibly a protozoan, though recently some evidence indicates it is caused by a filtrable virus. It is carried, as is the germ of malaria, by a certain genus of mosquito (*Aëdes*). Severe outbreaks of the disease have occurred in Louisiana, Mississippi, and Alabama; and there have been occasional outbreaks in Philadelphia and Baltimore.

Yellow fever is more deadly than malaria. From 12 to 80 per cent of those who contract the disease die from the attack. In Rio de Janeiro, in 1898, 94.5 per cent of those who contracted the disease died. Yellow fever was traced to the mosquito as the result of extensive work by a group of American doctors. (The story of the conquest of yellow fever is told on pages 508–509.)

Recently the United States Public Health Service has taken steps to prevent the importation of yellow fever from South American countries where it is



Life history of the mosquito. What means will aid in exterminating mosquitoes? Why will a layer of oil on the water kill the young? Why, during the Second World War, did our armed forces in the tropical jungles so often become ill with malaria?

known to exist. All airplane crews are being vaccinated against yellow fever. The planes are closed as soon as they land, and the interiors are sprayed with insect poison to kill any mosquitoes that might be there.

Self-test. 1. Malaria, as well as --?--, is spread by (1) houseflies; (2) mosquitoes; (3) ticks; (4) other people having the disease; (5) rats.

2. If all the insect carriers of diseases could be killed, there would be *few* cases a hundred years hence.

3. Certain fish are proving valuable in reducing the carriers of the --?-- parasite.

4. The parasite of --?-- feeds upon the *white* corpuscles of the blood.

Self-test on Important Biological Terms

immunity
serum
toxin-antitoxin
toxoid
vaccination

Social Implications. What are the social implications of spitting? of having cows tested for tuberculosis? of the compulsory use of the Schick test and of the toxin-antitoxin immunity treatment for diphtheria?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Why is a horse a better animal to use in securing antitoxin serum than a guinea pig or a mouse?

2. Why is it important to recognize early the symptoms of such diseases as measles, diphtheria, and whooping cough?

Exercises on Scientific Method. 1. *Making Inferences from Data.* Certain tsetse flies are the carriers of African sleeping sickness. The insects are found in forests or underbrush, but seldom in cleared fields around dwellings. They are somewhat larger than a housefly and suck blood as a mosquito does. They are most troublesome during the hotter parts of the day. From these facts, state the plan one might make to prevent contracting African sleeping sickness.

2. *Making Hypotheses.* How do you explain the fact that in Michigan there are malarial mosquitoes, but there is no longer any malaria?

Exercise on Scientific Method and Scientific Attitudes. The story of how the American doctors proved that yellow fever is caused by a germ carried by a certain genus of mosquito is one of the most interesting in the history of science. Dr. Walter Reed, a major in the United States army, was in charge of the commission, which included also Dr. James Carroll, Dr. Aristide Agramonte, and Dr. Jesse Lazear.

Dr. Reed first studied the known facts about how the disease was contracted. He found that those who nursed yellow-fever patients or were around those sick with the disease did not seem to take the disease. It seemed likely, therefore, that the disease was not spread from patient to well person in the same ways that diphtheria and other bacterial diseases are spread. But though it might not be passed in these ways, it still might be contracted from garments and bedding used by yellow-fever patients. To find out whether this was true, Dr. Reed called for volunteers to live in a hut by themselves, to wear the clothing worn by yellow-fever patients, and to sleep in bedding in which they had died. None of these volunteers contracted the disease. He was therefore convinced that yellow fever could not be contracted in this way.

He had noted that some people living in the neighborhood where cases of yellow fever were first reported usually became sick with the disease two or three weeks after the first case. This suggested to him that there must be a carrier. The mosquito was suspected. To test this theory, Dr. Carroll purposely allowed one of the suspected mosquitoes to bite him. A private, Dean, allowed himself to be bitten by the same mosquito. Both men became sick with yellow fever but recovered. When a little later one of the suspected mosquitoes lighted on Dr. Lazear's hand, he likewise allowed it to bite him. He took the disease and died.

These cases seemed to indicate that the carrier had been found. But further experiments were necessary before the commission could be sure. Dr. Reed, therefore, called for volunteers who would offer themselves for experiment. He had to use people because no animal was then known which was subject to yellow fever. Two men, Kissinger, a private in the army, and Moran, a clerk, knowing fully the dangers they braved, placed themselves at Dr. Reed's disposal. These men were kept by themselves for several weeks, where there was no danger that they would take yellow fever. They then allowed themselves to be bitten by the suspected mosquitoes. Both took the disease, but both recovered. Dr. Reed and the other members of his commission were then satisfied that the mosquito was really the carrier of yellow fever.

Which of the scientific attitudes (see page 624) are illustrated by the various steps in the study of yellow fever? In what respects were Dr. Lazear, Private Dean, and Dr. Carroll controls? In what respect were Kissinger and Moran controls? Was it necessary that Kissinger and Moran should be kept by themselves for some time before they were allowed to be bitten by the mosquitoes? Explain. What further evidence would be necessary beyond that described here before the doctors could be certain that yellow fever was not passed directly from a sick person to another person? that it was not contracted from clothing and bedding used by patients? Did these experiments prove that the mosquito was the only possible carrier? Explain. Did Dr. Reed employ Koch's four steps in investigating this disease (p. 490)? If so, trace the four steps through Dr. Reed's investigation.

Special Report. During the Second World War the quantities of quinine available to our armed forces in the tropics were far below those needed. What substitutes for quinine have been developed by our chemists? How effective are these substitutes?

CHAPTER XXVI

Improving Health through Personal and Social Uses of Biology

Questions This Chapter Answers. 1. What are some health habits which are related to eating? · 2. What should one know about the ways of increasing or decreasing one's weight? · 3. What are food fads? · 4. What are food sensitization and food poisoning? · 5. How should one care for the teeth? · 6. What are some health facts in relation to respiration? · 7. How is artificial respiration administered? · 8. Why are rest and sleep necessary to health? · 9. Why should one cultivate good posture? · 10. How should one care for the eyes and ears? · 11. What is the hygiene of the skin? · 12. What are some applications of first aid? · 13. What is preventive medicine? · 14. What are the values and the defects of the pure food and drugs laws? 15. Are alcohol and tobacco harmful? · 16. What are some important guides to mental health?

HOW ARE FOOD HABITS RELATED TO HYGIENE AND HEALTH?

Eating customs. Eating at regular times is not practiced by wild creatures. Wild animals and usually savages eat whenever they can find food. Only civilized man and the domestic animals which he controls have regular mealtimes. The number of daily meals, their nature, and the hours at which they are served vary considerably, however, in different civilized countries. In parts of Europe, for example, four or five meals per day are served, and five meals daily are commonly made available on ocean liners. The hearty English breakfast is, moreover, a very different sort of meal from the light "Continental breakfast" served in many of the other countries of Europe. Also, the typical Southern breakfast is a very different type of meal from the breakfast served in New England or the Far West.

Eating customs, such as those which have just been mentioned, vary widely throughout the world and may change frequently. But the laws of health related to food habits remain the same everywhere. Health habits should be based upon a knowledge and practice of these laws.

Hygiene and digestion. Meals should be unhurried. The habit of eating too rapidly is said to be a common American fault.

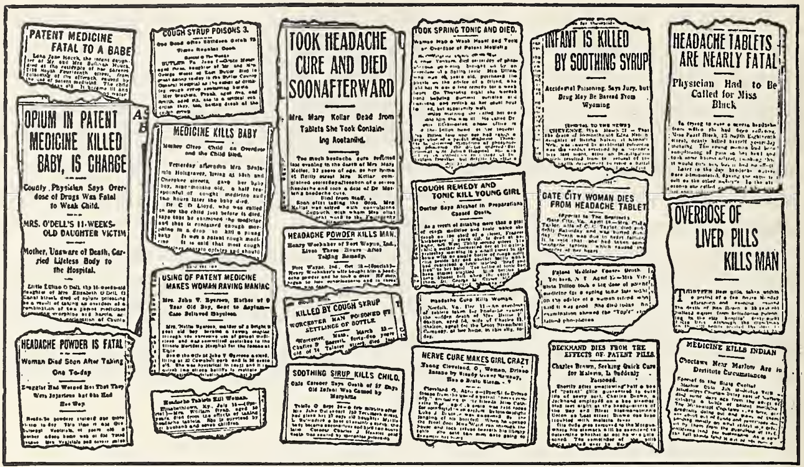
The digestive functions cannot take place normally when one is too tired. It is usually desirable, therefore, to rest for a short time before meals. One should also rest awhile after a meal, since violent exercise immediately after a meal interferes with digestion. One who takes daily exercise is less likely to have digestive troubles than one who takes little or no exercise. Fear and worry interfere with normal digestion. Meals should therefore be pleasant times during which only pleasant topics are discussed.

Regularity in elimination of intestinal wastes is highly desirable. If one gets a sufficient amount of exercise and eats a well-balanced diet, one will seldom be troubled with constipation. Drinking either hot or cold water before breakfast often aids in preventing this condition. One should avoid the use of medicines for constipation, except with the advice of one's physician, because their use may not remove the cause of the trouble. Also, if such medicines are used often, much harm may result because in time the intestines may become unable to function without them.

One of the commonest diseases of the digestive tract is appendicitis. It was formerly thought that this disease is caused by the entrance of seeds or other small hard objects into the appendix. This belief is no longer held. It is now known that the opening into the appendix is too small to permit even grape seeds to enter. Also, it is now known that appendicitis is caused by bacteria which attack the walls of the appendix.

What values are there in recreation such as this?

Galloway



PATENT MEDICINE FATAL TO A BABE

OPIUM IN PATENT MEDICINE KILLED BABY, IS CHARGE

County Physician Says Overdose of Drugs Was Fatal to Weak Child.

MRS. O'DELL'S 11-WEEKS-OLD DAUGHTER VICTIM

Mother, Unaware of Death, Carried Lifeless Body to the Hospital.

HEADACHE POWDER IS FATAL

Woman Died Soon After Taking One To-day

COUGH SYRUP POISONS 3.

MEDICINE KILLS BABY

Mother Gives Child an Overdose and the Child Died.

USING OF PATENT MEDICINE MAKES WOMAN RAVING MANIAC

Headache Tablets Kill Woman.

TOOK HEADACHE CURE AND DIED SOONAFTERWARD

Mrs. Mary Kollar Dead from Tablets She Took Containing Acetanilid.

HEADACHE POWDER KILLS MAN.

KILLED BY COUGH SYRUP

WORCESTER MAN POISONED BY SETTLINGS OF BOTTLE.

SOOTHING SIRUP KILLS CHILD.

TOOK SPRING TONIC AND DIED.

COUGH REMEDY AND TONIC KILL YOUNG GIRL

Doctor Says Alcohol in Preparations Caused Death.

Headache Cure Kills Woman.

NERVE CURE MAKES GIRL CRAZY

INFANT IS KILLED BY SOOTHING SYRUP

Accidental Poisoning, Says Jury, but Drug May Be Barred From Wyoming

GATE CITY WOMAN DIES FROM HEADACHE TABLET

Patent Medicine Causes Death.

DECKHAND DIES FROM THE EFFECTS OF PATENT PILLS.

Charles Brown, Seeking Quick Cure for Malaria, Is Suddenly Poisoned.

HEADACHE TABLETS ARE NEARLY FATAL

Physician Had to Be Called for Miss Black

OVERDOSE OF LIVER PILLS KILLS MAN

MEDICINE KILLS INDIAN

Choctaws Near Marlow Are in Destitute Circumstances

American Medical Association

Why is self-drugging dangerous?

Severe stomach-ache is sometimes a symptom of appendicitis. The first pains may be located in any part of the abdomen, though the appendix is on the right side of the body. The first impulse of many people when they have a severe pain in the abdomen is "to take some medicine." But taking any medicine to relieve constipation is dangerous if the pain is due to appendicitis. It may cause a diseased appendix to burst and so decrease the chances of recovery. The proper treatment of a person who has severe pains in the abdomen is to put him to bed, give him no food, apply an ice bag to ease the pain, and call the doctor.

Increasing or decreasing one's weight. There are some patent medicines which are advertised as enabling the user to put on extra weight, and a much larger number that are sold as means of reducing one's weight. These, like other patent medicines, advise the same treatment for everybody who has or thinks he has certain symptoms. The "remedies" fall into two classes, those for external use and those to be taken internally. The former, while possibly not harmful, are wholly worthless. The latter are usually harmful. Moderate eating is likely to keep one from becoming too fat. The American Medical Association[1] publishes a pamphlet dealing with dangerous and worthless cures for excessive weight. It also publishes a book which gives advice, based on the best medical authority, on the question of what diets to follow to increase or decrease one's weight. In cases of under-weight or over-weight which do not respond to these instructions concerning diet, it is best to follow the advice of a physician rather than to experiment, since one may be too fat or too thin for any of a number of causes.

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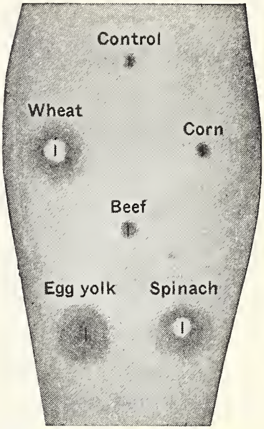
[1] The American Medical Association publishes a large amount of material concerning patent medicines and stands ready to answer any questions on the "patent-medicine problem" that may be submitted to it. The address of the association is Chicago, Illinois. The Canadian Medical Association, located at Montreal, Quebec, with branches in Ottawa and Toronto, Ontario, is likewise a source of information on all matters related to health.



Skin tests for food sensitization.[1] This person is sensitized to wheat, spinach, and egg yolk. How does the "control" enable us to know this?

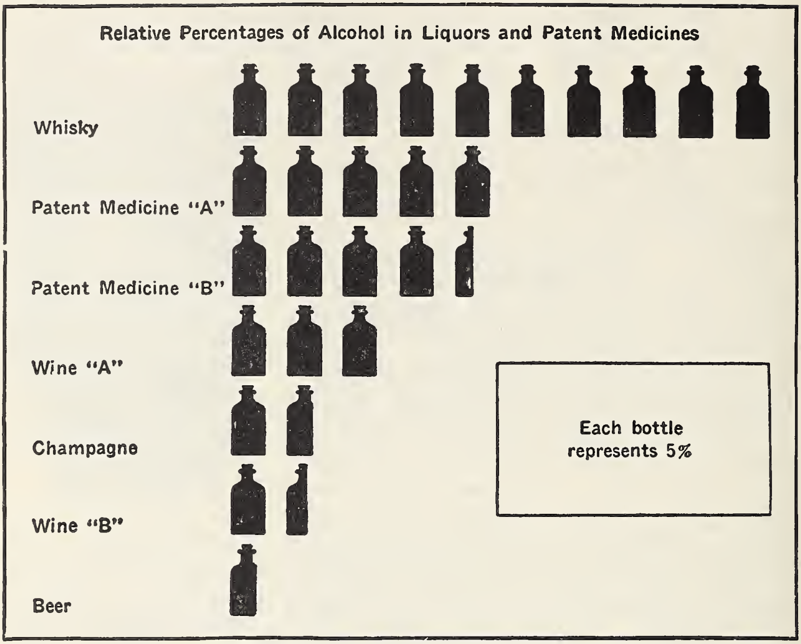
Food fads. There are fads, or styles, in eating which some people follow just as they follow other styles. These include vegetarianism, or eating only vegetable foods, the milk-diet fad, and the raw-food fad, or eating only raw fruits and vegetables. Yet another is the fantastic idea that it is harmful to eat proteins and carbohydrates at the same meal, although most of our commoner foods contain both proteins and carbohydrates. Still another, sometimes adopted by many young women who desire to become very slim, consists in eating considerably less than is necessary for health and proper development. This fad results in serious dangers. It may, for example, reduce the resistance of the body to a point at which the person may easily contract tuberculosis or some other dangerous disease if such a person comes in contact with sources of infection.

None of these fads is based on scientific evidence which establishes its value. Therefore all should be avoided. The best plan is to eat moderately a balanced diet consisting of a wide variety of animal and vegetable foods. Every day's diet should contain both energy foods to supply carbohydrates, proteins, and fats, and fruits and green vegetables to provide vitamins and mineral salts.

Food sensitization. Some people are sensitized to certain foods; that is, such people become sick with asthma, hives, eczema, or other illnesses whenever they eat these foods.[2] Sometimes the food which is causing the difficulty is easily discovered, but often it is not. One method used by physicians in discovering whether a patient is sensitized to certain foods is that of "skin tests." Tiny scratches are made in the skin of the forearm. Nothing is done to one of

[1] Andress, Aldinger, and Goldberger's *Health Essentials*, Ginn and Company.

[2] Illnesses of this type are called food idiosyncrasies. These idiosyncrasies are included among the diseases known as allergies.



The relative percentage of alcohol in certain liquors and patent medicines. What danger is there in the use of such patent medicines?

these scratches, which serves as the control. But a small bit of each of a number of powdered foods is gently rubbed into each of the remaining scratches. After a few minutes each scratch which contains a food to which the patient is sensitized may swell much like a mosquito bite.

Some doctors prefer to use a slightly different kind of test for food sensitization. In this test solutions of the food samples are inserted beneath the skin with a hypodermic needle.

Hay fever, which is similar to food sensitization, is caused by various pollens. It is often successfully treated by inoculations with the pollens that cause the disease. More or less immunity may also be acquired from the inoculations.

Alcohol and digestion. Scientific evidence is conflicting with respect to the effects of alcohol on the digestion. Most physicians, however, would probably accept these statements: The more concentrated alcoholic drinks, when taken before or during meals, do not help the digestive processes. Rather they hinder digestion by decreasing the quantity of enzymes which the various glands normally produce. Moreover, alcohol has a harmful effect upon the linings of the stomach and the intestines. The safest plan is to use alcohol only when it has been prescribed by a physician.

There are many so-called patent medicines which claim to be aids to digestion or cures for indigestion. Some of these, while harmless, are worthless. Others, however, contain alcohol in harmful quantities and may present a serious possibility of acquiring the drink habit from their continued use.

Tobacco and digestion. Many people believe that tobacco serves as an antiseptic in the mouth. This belief does not have sufficient scientific foundation. Smoking does, however, have harmful effects on digestion. Those who smoke much are likely to suffer from coated tongue, bad taste in the mouth, irregular appetite, absence of taste, nausea, and a sensation of heaviness in the stomach. Also, heavy smoking is liable to result in injury to the liver and the pancreas.

Self-test. 1. Patent medicines taken internally for digestive troubles *seldom* do harm and *usually* effect a cure.

2. It is sensible to control one's weight with *patent medicines.*

3. Food fads are *usually* based on scientific evidence.

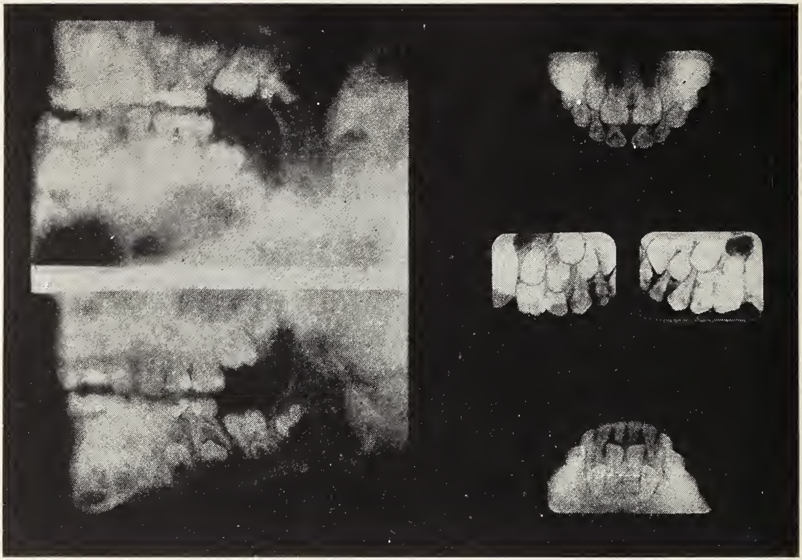
4. Food sensitization can *sometimes* be corrected by diet.

5. Alcohol and tobacco are believed by scientists to be *helpful* to digestion.

WHAT SHOULD ONE KNOW ABOUT THE HYGIENE OF THE MOUTH?

The order in which the teeth appear. The first teeth to appear in a baby's mouth are the incisors. These are shown in the figure on page 313. They begin to push through the gums a few months after the child's birth. Other teeth grow one after another behind the incisors, but in no definite order, until the first set of twenty deciduous teeth is entirely complete. When the child is about six years old, the first permanent teeth appear. These are the "six-year molars." They grow behind the deciduous teeth, one on each side of each jaw. When a child is about twelve years old, another molar grows behind each six-year molar. By the time a child is twelve or fourteen years old, the second set, or permanent teeth, have one by one taken the places of the deciduous teeth. The molars of the deciduous set are replaced with premolars in the permanent set.

The last teeth to grow in are the third molars, or wisdom teeth. These generally come when one is nearly grown. Sometimes one may be thirty years old or even older before they appear. The wisdom teeth are frequently small,



Dr. George R. Moore

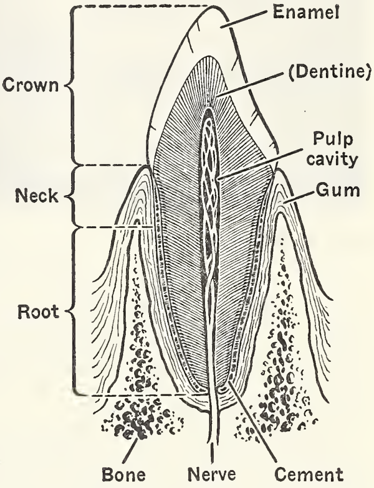
X-ray picture of the jaws of a child. This photograph, taken at the age of six and one half years, shows all the permanent tooth buds except those of the wisdom teeth. **Can you** locate the "six-year molars" and the second molars?

not well formed, and of little use. They should, however, be kept if possible until the face has completed its development. Sometimes one or more of the wisdom teeth, as well as other teeth, never appear at all. Sometimes there are extra teeth. The full set usually includes thirty-two teeth.

Early dental care. Proper care of the teeth should be provided for young children. Many people do not realize that the first permanent teeth usually appear before any of the temporary teeth are lost. If a child's teeth are neglected on the theory that "they will come out anyway," the six-year molars may be injured.

At about the age of five every child should have a complete X-ray examination of the mouth to determine whether all the permanent teeth are forming. In about 99 per cent of the cases all but the wisdom teeth can then be detected. These will be shown by an X-ray photograph taken at the age of eight or ten. In case the plates show that extra teeth are forming, these should have the attention of a dental surgeon at once.

Care of the teeth. Bacteria multiply in particles of food left on or between the teeth. Besides affecting the teeth themselves, the poisons produced by the bacteria of decay cause bad breath. Since some of the poisons are absorbed by the blood in the digestive organs, these poisons may cause a number of serious illnesses, such as neuritis and rheumatism. If the gums become infected the poisons that are formed may pass directly into the cells and blood vessels by osmosis. Some foods, especially sweets, may produce acids which attack the enamel of the teeth.



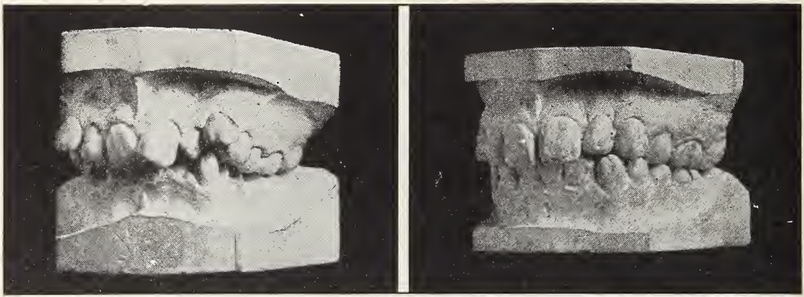
Why is it desirable to brush thoroughly both the enamel and the gums?

*Because of the facts just stated it is a wise plan for every person to have his teeth examined by a dentist about every six months. If any teeth have begun to decay, the dentist will fill the cavities and stop the spread of the decay. Even if there are no cavities to fill, the dentist should give the teeth a thorough cleaning.

If the teeth are crowded and uneven, effective chewing may be difficult and the face may not develop normally. In such cases it is often desirable to seek the assistance of a special dentist (called an orthodontist) to restore the teeth, if possible, to their correct position. This he is able to do by means both of exercises which he prescribes and of special braces which he designs and which gradually force the teeth into correct position.

Mouth-washes and dentifrices. Extravagant claims are often made through advertising in magazines and over the radio for antiseptic mouth-washes which are represented as killing germs in the mouth, as preventing decay, or as giving a pleasant breath. Similar statements are made for dentifrices, that is, preparations for cleaning the teeth, which are said to prevent decay and to cure diseases of the gums.

A mouth-wash has little value except to rinse away food particles after these have been loosened by brushing. Even if mouth-washes kill germs, little or no benefit is gained, because soon after the antiseptic is used there will be as many germs in the mouth as before. A home-made mouth-wash consisting of half a teaspoonful of common salt, with perhaps a little baking soda, dissolved in a glass of warm water will serve as well as anything of the sort which can be bought.



Dr. George R. Moore

Two models of the same jaw, before and after orthodontia. What advantages are gained from such treatment?

Teeth are made clean by thorough brushing and not by dentifrices. No dentifrice will cure or correct diseases of the gums (such as pyorrhea) or bleeding, spongy, or receding gums. No dentifrice is an effective antiseptic. None of them preserve the teeth.

Dentifrices are made of such common things as precipitated chalk, soap, salt, baking soda, borax, magnesia, glycerin, alcohol, and water, together with flavoring and coloring matter. As good a dentifrice as any can be made of equal parts of soda and common table salt to which is added, if desired, a little oil of peppermint or wintergreen for flavor. Teeth should be cleaned regularly night and morning, and the mouth should be rinsed thoroughly after each meal.

Self-test. 1. The normal number of deciduous teeth is --?--.

2. The normal number of permanent teeth is --?--.

3. The deciduous teeth should be *extracted* as *soon* as possible after the permanent teeth begin to grow in.

4. Select from the following list of practices in the care of the teeth the desirable ones: (1) visit the dentist about every six months; (2) use patent antiseptic mouth washes; (3) brush the teeth regularly twice a day; (4) use only the dentifrices which are advertised over the radio; (5) consult a special dentist (orthodontist) if your teeth are irregular; (6) rinse the mouth after a meal; (7) have an X-ray photograph taken of a child's teeth when it is about five years old.

HOW ARE HYGIENE AND HEALTH RELATED TO RESPIRATION?

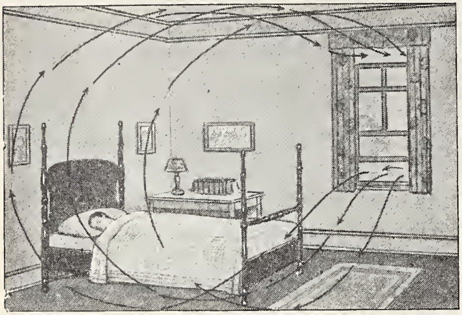
Hygiene of respiration. If the respiratory system is normal and healthy, one breathes through the nose and not through the mouth. Persistent mouth breathing is an almost certain symptom that something is wrong with the breathing apparatus. The trouble may be due to adenoids, which are unnatural growths of certain tissues in the rear of the nasal cavity. Or it may be due to the fact that bones or tissues in the nose may have grown out of place in such a way as partly to close the passages. The results from any of these causes may be frequent colds, irregular development of the teeth and palate, and, in extreme cases, deafness. Such troubles may usually be avoided by having a thorough examination from time to time by a physician. In case of serious respiratory trouble a specialist in diseases of the ear, nose, and throat should be consulted.

Years ago it was common for women to wear tight corsets. These corsets were constructed so as to restrict the waist and to produce an unnatural "hourglass" effect. There is abundant scientific evidence which proves that the wearing of such corsets resulted in serious harm. Recently there has been a tendency by some of the style-makers to reintroduce tight corsets for women. Only the good sense of American and Canadian women can prevent the spread of this foolish and dangerous style.

Deep breathing. It used to be thought that everybody should learn to breathe as deeply as possible. Special breathing exercises were practiced for the purpose of increasing the capacity of the lungs. It is now no longer believed that such exercises are of benefit. On the contrary, with some people—for example, those who are suffering from tuberculosis—such breathing exercises are likely to be harmful. If a person is in good health, he need not be concerned about his breathing, because he will naturally breathe the quantities of air he needs for his various activities. Cultivating the habit of maintaining a good posture will help to ensure that one's breathing will be proper. One should avoid wearing tight clothing which prevents free and comfortable breathing.

Tobacco and respiration. Some recent experiments indicate that the use of tobacco may result in real harm to the respiratory system. There is some evidence that smoking may cause cancer of the lungs. A study of more than six hundred men showed that smokers were more often ill with acute respiratory diseases than non-smokers. Those who inhale cigarette smoke are more likely to contract laryngitis than those who do not. "Smoker's asthma," a disease which makes difficult the drawing of a full breath, may also result from excessive smoking. Moreover, there is considerable evidence to prove that tobacco is harmful to young people. The student who smokes is in general less successful, both in athletics and in school work, than the one who does not.

Ventilation. Contrary to popular belief, the air contains a far greater percentage of oxygen than is needed for oxidation and the consequent release of energy within the body cells. Therefore ventilation is not usually needed in order to supply necessary oxygen or to remove the excess of carbon dioxide produced by respiration. In fact, one may breathe the same air over and over without injury and without discomfort, provided the air is kept circulating.



Can you explain why the air currents move in the direction of the arrows? (If you cannot, look up the subject of ventilation in a textbook of general science or physics)

*The circulation of air through ventilation serves chiefly to reduce the quantity of water vapor in the air immediately around the body. If the vapor content is high and if the air is still, not much sweat can evaporate. The reason is that the air, especially that next the skin, soon becomes saturated. Therefore the body cannot then get rid of its surplus heat through evaporation of sweat. Ventilation does to some extent help to remove an excess of heat from the body surfaces. Circulation of air through ventilation serves also to remove foul odors. These, however, are more likely to be unpleasant than to be harmful.

Self-test. 1. A normal person breathes through his --?--.

2. Taking breathing exercises to increase the lung capacity is now considered *desirable*.

3. There is considerable scientific evidence which tends to prove that the use of tobacco is *harmful* to the respiratory system.

4. The chief purpose of ventilation is to --?--.

5. The greater the amount of moisture in the air, the *easier* it is to become cool.

HOW CAN OTHER DAILY ACTIVITIES PROMOTE HEALTH?

Rest and sleep necessary to health. Fatigue results from any kind of activity which is continued over too long a period. Active muscles are constantly using energy. Protoplasm is constantly breaking down, producing waste products which to some extent serve as toxins, or poisons. As these increase in quantity, they interfere more and more with muscular action. During the period of activity these waste products are produced more rapidly than they

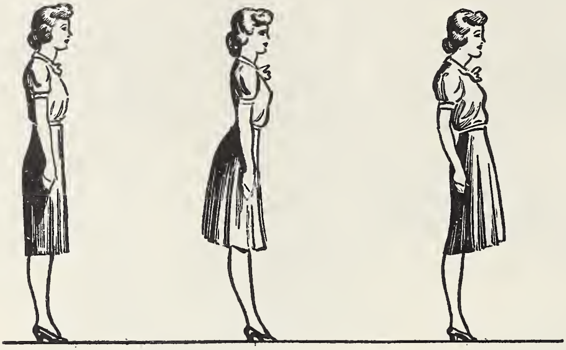
United States Department of the Interior

Recreation in Sequoia National Park, California. How do such activities promote good health?

can be removed. Consequently one becomes tired. One then needs rest or sleep to permit the removal of the waste products and the replacement of protoplasm.

The amounts of rest and sleep which different people require vary greatly. Napoleon and Edison were said to need far less than the average man or woman. A person should find out how much sleep he requires to feel well and to do his work most effectively. He should then make sure of getting this required amount of sleep. For the average adult the number of hours is about eight. For the growing boy and girl it is usually about nine or ten hours. Persons of advanced years require more sleep than those who are younger.

Somebody has said, "We become tired of work more often than we become tired by working." This statement means that a frequent change of work is desirable as a means of reducing fatigue. Variety of activity employs new sets of nerves and muscles, thus giving tired cells a chance to recover their normal state. Variety in itself gives pleasure. Great value is derived from exercise as a means of recreation. It should be kept in mind, however, that when one is greatly fatigued, activity, even that of play, will only add to the fatigue. In such a case, only rest and sleep will serve.



The best exercise to improve posture consists in assuming correct standing, sitting, and walking postures many times a day. Explain. Which of these three poses illustrates correct standing posture?

The effects of alcohol on muscular work. Extensive experiments have given results which show that even a little alcohol decreases the amount of effective work which one can accomplish. A person may even try to work harder after taking some alcoholic drink,—that is, he may use up considerably more energy in attempting to do the same task,—but he will accomplish less than at times when he has taken no alcohol. Moreover, fatigue is not removed by alcohol. The belief that it is, is due to the fact that alcohol affects the higher nerve centers and therefore interferes with one's judgment.

Good posture. The bones and muscles make up a large part of the body and by their position exert great influence on the internal organs. When a person becomes careless of his sitting and standing positions and permits bad posture habits to develop he may permanently and seriously injure his body. Especially is it true that young people need to form good posture habits. The reason is that the bones of young people include much cartilage and can therefore be given the form that they are likely to keep throughout life. Bending over too long at a time to write or do other close work and holding the head forward in standing and walking may cause round shoulders. Sitting at a desk with one arm held on the desk to write while the other rests in the lap may tend to cause curvature of the spine.

There are good reasons, other than concern over our physical well-being, for acquiring good posture. Every one of us likes to have a good appearance. A person who stands, sits, and walks gracefully has more poise and self-confidence than he otherwise would have. Careless habits of posture are likely to give to others the impression that we are careless also in our thinking and in the performance of our duties.

Hygiene of the feet. Some of the serious foot troubles are caused by straining the foot muscles and leg muscles. Such strains may be due to too much walking or standing or to ill-fitting shoes. Weakening of the muscles and tendons may cause fallen arches, which are accompanied by great discomfort. One should be careful always to select for daily wear shoes which have low heels and are big enough to be comfortable. In walking, one should point the toes straight ahead, to prevent muscular strain.

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The Score-keeper. **Project No. 23:** From your local police department secure facts concerning the percentage of automobile accidents due to drunken driving, recklessness, carelessness, and the like. Make a bulletin board display of these facts

Corns and blisters are caused by the rubbing of ill-fitting shoes. A broken blister may become infected and hence should be bandaged to prevent the entrance of dirt and germs.

Hygiene of special sense organs. **The eyes.* Our eyes are not likely to serve us well for life unless they always have the best possible care. Therefore avoid straining the eyes. Do not read or sew in a flickering, dim, or fading light. Do not read when there is a glare upon the paper. When the sunshine is bright, wear amber-colored or blue glasses while driving or while playing such games as tennis or golf.

*The safest rule to follow in case of real or suspected troubles with the eyes is to consult a specialist in eye diseases. Dizziness, headache, and sometimes indigestion may be symptoms of defective eyesight. Moreover, many people suffer more or less from the need of glasses without knowing that they do. Recently, for example, a boy who had done excellent school work through the eighth grade was discovered to have only two-fifths normal vision. It is prudent, especially for young people, to consult an eye specialist every year or so, even though no definite symptoms of trouble have appeared.

Rubbing an injured or inflamed eye is liable to irritate it more seriously. Cinders or dust can sometimes be removed from the eye (1) by using a corner of a clean handkerchief, (2) by pulling the upper lid over the lower one and then winking rapidly, or (3) by bathing the eye in warm water containing boric acid. The eye is so delicate and complex, however, that only a specialist should attempt any but simple first aid.

The ears. *Deafness may result from a number of causes. These include injury to the eardrum and infections of the middle ear, such as are often caused by diseased tonsils and by adenoids. Earache is often a symptom of such an infection. If the pus produced cannot escape through the tube to the throat (Eustachian tube), the eardrum may burst. In case of disturbing symptoms in the ear, therefore, it is always safest to consult a physician—if possible, an ear specialist.

Do not thrust any sharp instrument into the ear, because in so doing there is danger of injuring the eardrum or the membrane lining the canal. A shout directly in the ear or a blow on the ear has been known to produce deafness by bursting the eardrum. Do not blow the nose violently or hold the nostrils while blowing the nose. By so doing there is danger of spreading infection by forcing harmful bacteria into the middle ear. Do not use nose drops or ear drops except with a physician's approval of the kind used and of the way in which they are used. The person who has been made immune to scarlet fever and diphtheria has decreased his chances of the ear infections which these diseases are likely to produce.

Many patent medicines and "eardrums" are on sale which are said by their manufacturers and advertisers to relieve ear troubles and deafness, but they will do no good and may do serious harm. For those who have defective hearing, however, there are on the market several electrical aids to hearing that are of value.[1]

Hygiene of the skin. It is stated that the people of a certain small nation of Asia never bathe. They believe it is sinful to do so, because they think dirt is given to them by the Creator as a covering and protection for their bodies. These people frequently have foul sores and loathsome skin diseases on their filthy bodies as a result of not keeping clean.

Bathing is necessary to free the skin of germs that might cause infections. But probably its chief value is to improve our personal appearance and to re-

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[1] Some of these hearing devices, however, are advertised by statements that go far beyond the facts. Much valuable practical information for those who are deaf may be obtained from the American Federation of Organizations for the Hard of Hearing, Washington, D. C.

National Parks Bureau of Canada

Why is there danger of severe sunburn when one is near a body of water? What is a heliophobe?

move body odors. A warm bath should be part of our personal grooming program. Cleanliness of the skin is an important aid in preventing the pimples and blackheads which trouble many young people.

The effects of sunshine on the skin are healthful and stimulating. But the time of exposure to the sun's rays should not be too long. One should avoid severe sunburn, which is always painful and may be very serious.

Within the last few years many types of electric lamps have been manufactured and sold with the statement that they provide "artificial sunlight" in the home. The Council of Physical Therapy of the American Medical Association has made extensive investigations of these lamps. It announces that a few, if properly used, (1) give benefit in cases of rickets, a disease of childhood which is caused by improper diet and which results in a softening and deforming of the bones, and (2) aid in developing sound bones and teeth. The association, however, does not accept the claims that the use of such lamps "increases the tone of the tissues or of the body as a whole, stimulates metabolism, acts as a tonic, increases mental activity, or tends to prevent colds." The American Medical Association furnishes free information concerning the sun lamps which it approves.

Self-test. 1. When one is very tired, the best thing to do is to *exercise.*

2. It is *less* important for young people to practice good posture than for older people to do so.

3. In walking the toes should be pointed *slightly inward.*

4. Alcohol enables one to work *more* effectively.

5. In case of eye trouble or ear trouble one should --?--.

6. Sound advice with respect to sun lamps may be secured from the --?--.

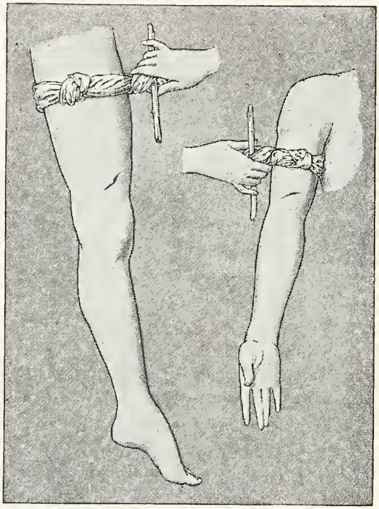
WHAT SHOULD EVERYONE KNOW CONCERNING FIRST AID?

Prevention of accidents. *Every year many people are injured or killed in accidents which occur in their own homes. Most of these accidents could be prevented. Many safety committees suggest rules such as these: (1) place lights above dark stairways; (2) anchor small rugs so that they will not slip; (3) use a step-ladder and not a chair to climb on; (4) put matches, poisons, and sharp utensils, as knives and scissors, out of the reach of small children; (5) do not use inflammable materials, like gasoline, for starting fires or for any other purpose whatever inside the house. But even when one is careful to follow these and other safety rules, many kinds of accidents are likely to occur, and one should know proper first-aid measures to use before the doctor arrives.

Broken bones. If you suspect that a bone is broken, you should take great care not to move it. If a simple fracture is moved, it may become a compound fracture, that is, one in which the ends of the bone project through the flesh and skin. If a person who has a broken arm or leg must be moved, the broken bone should first be padded and supported with splints to prevent movement of the broken ends. Anything which is stiff enough may be used for a splint.

Doctors tell us that sometimes in automobile accidents well-meaning rescuers do more damage in moving the victims than was done by the accident itself. A person with a broken back or arm or leg may be seriously injured by being put into a car. He should be allowed to lie flat on the ground until a physician arrives. Death may result if a badly injured person is allowed to walk.

Fainting. When for any cause the brain receives an insufficient supply of blood, fainting is likely to result. The patient should be placed on his back with his head lower than the rest of his body so that the blood will flow quickly into the head. The clothing should be loosened, and the space about the patient should be kept clear of people, so that he may have plenty of fresh air. Cold water sprinkled on the face, but not thrown in quantities, sometimes helps to revive the patient. Smelling salts and household ammonia on a handkerchief held near but not touching the nose may likewise help. After the patient regains consciousness, keep him lying down for a time.

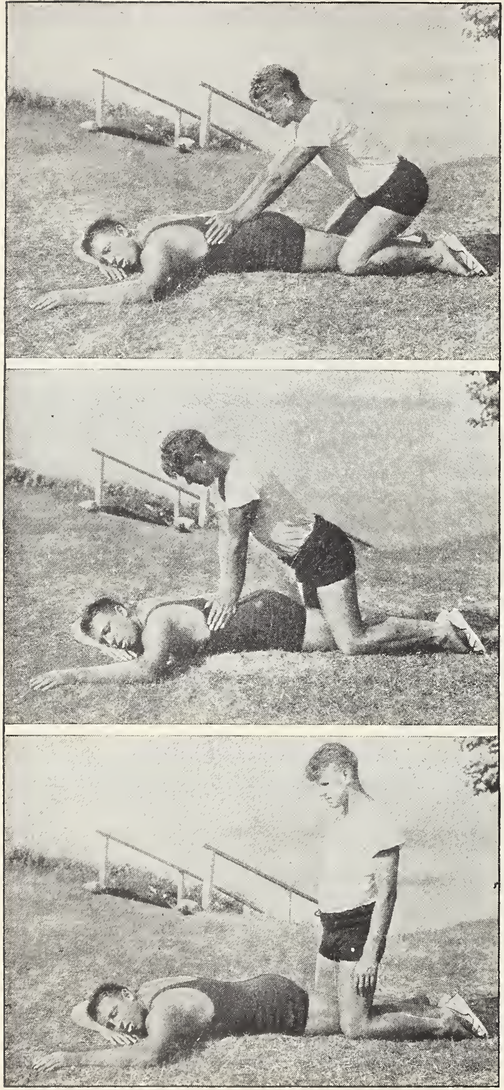


These tourniquets are correctly placed for severed arteries. Where should they be placed for severed veins? Can you discover any survival value in the fact that, in general, arteries lie deeper than veins?

Cuts and wounds. Cuts and scratches should be sterilized with tincture of iodine. Minor cuts and wounds should be bandaged with sterilized bandages, but not too tightly. Bleeding can usually be stopped in a minor cut or wound by holding up the injured part.

In case an artery or a vein is severed, pressure applied with the fingers above and below the wound should first be tried. If this treatment does not stop the flow of blood, a tourniquet should be applied thus: Tie a cloth around the member, and twist it sufficiently tight to stop the bleeding. If an artery has been severed, the blood will flow in gushes corresponding to the heart beat. In such a case, the tourniquet should be applied between the cut and the heart. If a vein has been severed, the blood will flow quietly. The tourniquet should then be applied on the side of the wound away from the heart. After ten or fifteen minutes the tourniquet should be slowly and cautiously loosened, thus permitting the blood to flow into the tissues freely, even though bleeding begins again. Unless this is done, serious results may follow, since, in order to heal, the tissues must be plentifully nourished by the blood stream. After the blood has flowed for a few minutes, the tourniquet may be made tight if the bleeding still continues. Keep the wound bandaged. Also, do not change the bandage often, since by so doing you are almost certain to start the bleeding again.

Bruises and sprains. In bruises the tissues are injured so that the blood flows out of the capillaries under the skin. The result is a "black and blue" appearance. Applications of very warm or cold water will hasten healing because



Artificial respiration is used in cases of carbon monoxide poisoning and severe electric shock, as well as in cases of drowning. **Special Report:** Artificial respiration

circulation is stimulated. Sprains are best treated by first soaking the injured part in hot water for fifteen or twenty minutes and by then applying cloths soaked in cold water. This treatment should be continued for several hours.

Self-test. 1. A person who has fainted should be placed with his *head* higher than his *feet.*

2. A tourniquet should not be kept tightly bound for more than *an hour.*

3. Artificial respiration is sometimes a means of saving life in cases of carbon monoxide poisoning, severe electric shock, and --?--.

HOW DO PUBLIC CIVIC ACTIVITIES CONTRIBUTE TO HEALTH?

Preventive medicine. Much of the work which is being done by doctors today concerns itself as much with preventing sickness as with curing it. People are learning that it is worth more and costs less to keep well than to be cured of illness. They have learned that it is wise to go to the doctor for examinations to check up on their health. Parents take their children, when they are very young, to the doctor to be inoculated against diphtheria, whooping cough, and sometimes other diseases. Most of us are vaccinated against smallpox, even though there are no cases of the disease to which we are likely to be exposed. If we are planning to travel in places where the water supply is not certain to be safe to drink, we are vaccinated against typhoid.

Many of our schools have school nurses or doctors and school health examinations. Many cities have free hospitals and clinics where all who need treatment, but who cannot afford to pay the usual prices for it, may obtain it. In some counties public-health nurses visit rural schools and homes to give health advice and to help in preventing disease and in caring for the sick. City, state, and Federal health officers aid in raising the standards of our health.

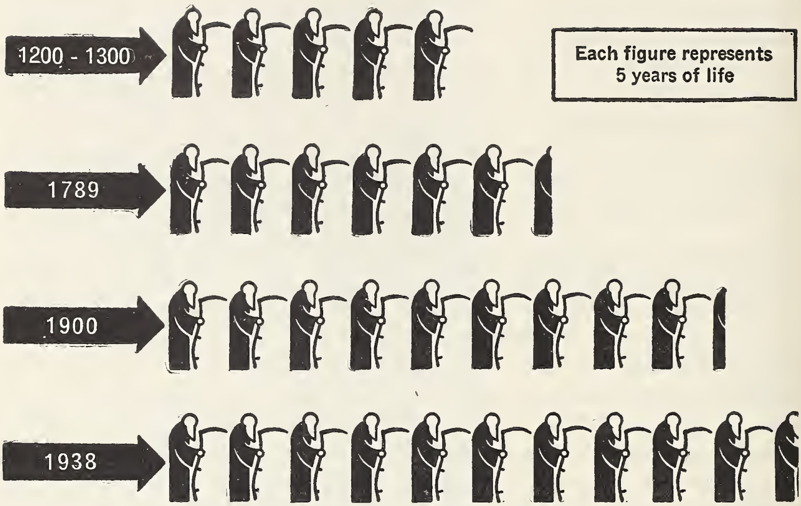
It is largely because of the improvement of our general health that people today may expect to live longer than their ancestors did. Wide-spread campaigns of public education have taught us how diseases may be prevented. Tuberculosis is no longer dreaded as it once was, for nearly everyone knows something about how it may be cured. There is reason for the hope that cancer and many other dangerous diseases will cause fewer deaths as people learn that when they are recognized in their early stages, proper treatment may prevent their development. The campaign which is being carried on today against syphilis may bring health and happiness to thousands of people. Newspapers, magazines, radio, motion pictures, and public lectures, all contribute much to public education concerning diseases.

Public services which protect health. It is unlikely that any of our great cities could exist today if it were not for the activities of the public-service organizations which protect the health of the people. The problem of securing a sufficient and safe water supply is one which requires constant attention.

Methods of sewage disposal are being improved in many places. When sewage from cities is emptied into rivers and lakes, the water is dangerously polluted. Modern sewage-disposal plants treat the sewage so that germs are killed, and the solid matter that is left can be used as fertilizer.

Most cities and towns have a number of regulations which help to ensure that food will be free from dangerous germs. Grocery stores and meat markets are inspected to make certain that food is displayed only in such a way that it is protected from flies and is prevented from being handled by customers. Slaughter-houses and meat-packing establishments must comply with certain health regulations. Restaurants, in many cities, must comply with certain standards of cleanliness and disinfection in their kitchens. Our milk supplies are subjected to the most careful control.

Pure food and drug laws. *Until 1906 there were no national laws in the United States to protect the buyer of canned goods from adulteration of foods.



People Live Longer Now

The number of years which the average person lived at various dates. This graph shows that six hundred years ago the average person lived 25 years. Can you find the average length of life for 1938?

The purpose of food adulteration is dishonest, since it usually means putting in the place of part of the food some other substance, an adulterant, which is less expensive to the producer. Thus milk is sometimes adulterated, by taking from it some of the cream and adding water in its place, and sometimes by adding substances to keep the milk from souring. Coal-tar dyes are sometimes added to soft drinks to make them attractive. Sweetened fats are sometimes used in chocolate fillings. White sand is sometimes added to sugar.

Sometimes the adulterants are merely harmless or less valuable as food than the substances to which they are added—for example, cereals in sausages. Frequently, however, the adulterant is harmful, as formaldehyde in milk, benzoate of soda in catchup or in sausages, or copper salts in canned vegetables to make them green.

Food substitutes must not be confused with food adulterants. A food substitute is a substance which can be secured in greater quantity and more cheaply than the food for which it is substituted. The substitute, however, often has a food value equal to that of the food for which it is substituted.

Thus oleomargarine or peanut butter is a substitute for butter. Potato flour and flours made from barley, oats, and other grains are substitutes for wheat flour.

During the World War the use of food substitutes was made especially necessary. The reason was the difficulty of feeding our own armies and people and at the same time of helping to supply food to our allies when so many of our men and women were withdrawn from normal food-producing industries to engage in various activities connected with the war.

In 1906 the Congress of the United States passed the Federal Food and Drug Act, which has helped to control the adulteration of many foods and statements made in the advertising of patent medicines. Under this law manufacturers were required to state on the labels of food packages and containers the composition of the food, its weight, and whether preservatives or coloring were used. Also, drug-manufacturers were required to limit their statements so as to include only the kinds of diseases which the medicine would remedy and to state the amounts of certain drugs that their products contained. This national law applied only to products sold outside the state in which they were made. Most states have similar laws which control products sold within the state.

These laws did not seem to be sufficient. For many years people recognized that additional food and drug laws would be desirable. The old laws imposed no control over the advertising statements which manufacturers might make for their products, in magazines and newspapers or over the radio. It has been maintained that some legal control of advertising is necessary because the average person is far more likely to accept advertising statements as true than he is to read the facts about a product on the package label. Additional laws have long been needed, too, to control the manufacture of "beauty preparations," or cosmetics, and of hair dyes, hair-removers, and the like.

A new law, called the Federal Food, Drug, and Cosmetic Act, went into effect on June 25, 1939. Like the previous laws, it requires that the labels on packages tell the truth about the composition of the product. In addition, it provides that any product which contains a drug that might be habit-forming must bear the statement "Warning—may be habit-forming." It further requires that drugs must be labeled with directions for their use and with a warning to the buyer against the dangers of using too much of the drug or of continuing its use to an extent which may be dangerous to health.

The new law also requires that instruments and devices intended to cure, treat, or prevent disease must be labeled to indicate any harmful effects they may have on the body if not used according to directions. Unfortunately, however, the government has no control as yet over the manufacture of such articles, and therefore cannot establish standards with which all manufacturers must comply in making these instruments.

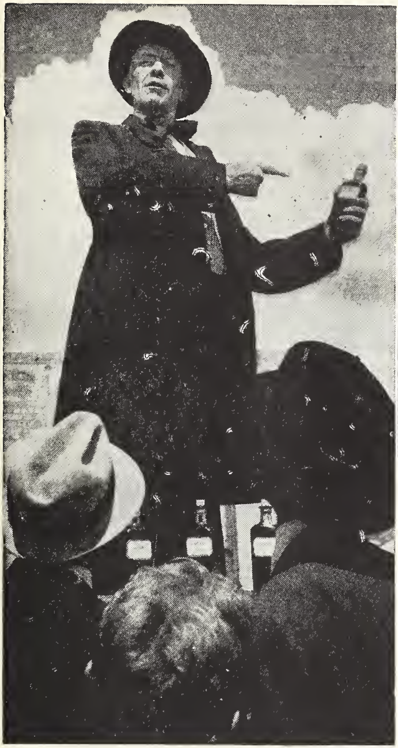
The provisions of the law which are concerned with cosmetics are very general, but afford some protection to the consumer, or one using the product. Poisonous ingredients can be included in such products only when it can be shown that they would not be injurious to the consumer under ordinary conditions. Thus coal-tar hair dyes are permitted if the label contains a warning statement, but coal-tar eye-lash dyes are forbidden.

Another law gives to the Federal Trade Commission the control of false or unfair advertising of foods, drugs, medical apparatus, and cosmetics. No false advertisements can be sent through the mails, nor can a manufacturer make false statements regarding his product in magazines or newspapers or over the radio. Any advertisement is considered false if it makes dishonest statements as to the value of the product, or if it fails to state the consequences which may result from the use of the product under ordinary conditions.

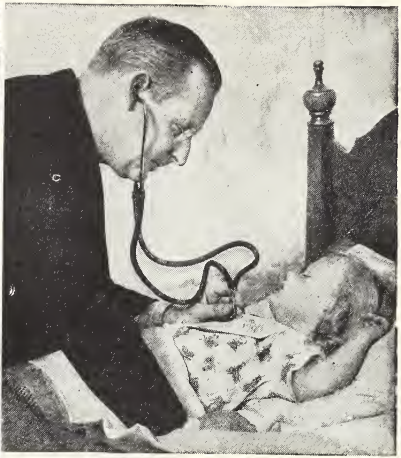
Canada has a Food and Drugs Act which is similar in many respects to that of the United States in that it regulates the adulteration of food and drugs. In addition, it has the excellent provision that no one may manufacture, import, or offer for sale any medicine which is labeled or advertised as a remedy for such diseases or disorders as cancer, blood-poisoning, diabetes, heart disease, obesity, and tuberculosis.

Patent medicines. The people of the United States spend $360,000,000 for patent medicines every year. This is a very great sum of money even if spent for things of real value. Unfortunately it is not. The best one can say of most patent medicines is that they are harmless but worthless. Some of them are definitely and seriously harmful and dangerous. Usually, moreover, although patent medicines are sold for high prices, they are made up of common and inexpensive substances.

Everybody who possesses and uses biological knowledge and scientific attitudes should find those of great help in considering the question of whether or not to use patent medicines. If a person has even an elementary knowledge of the structure and functions of his body, he knows how necessary it is to give the right kind of care to all its delicate parts. If, therefore, he becomes ill, he knows that only a doctor can give proper advice as to the necessary treatment. He knows that, with his own limited knowledge, he will not be able to determine the cause of his illness or the right methods to use in treating it. He is sure that the treatment prescribed by the doctor will be much more effective than any medicine he himself might choose, merely from reading advertisements or statements on the labels of patent-medicine bottles. He will know



Galloway



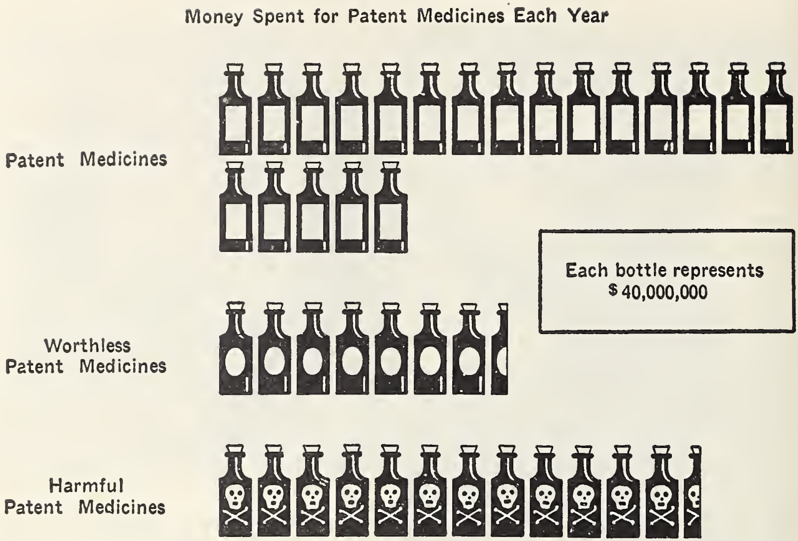
Roberts

An unscientific way of treating the sick: a seller of patent medicine. The scientific method of treating the sick: the doctor has just made his diagnosis, that is, he has just decided what is the nature of the disease.

Exercise on Scientific Method: Which of the elements of scientific method (p. 625) is the doctor using?

that those patent medicines which are said by their makers to be of value in the treatment of many different diseases are probably of no real value in the treatment of any of them.

There are a number of diseases, among them cancer, epilepsy, and tuberculosis, which cannot be helped by any drugs or medicines. There are certain ones, among them diabetes and other diseases of glands, and also certain diseases of the kidneys, which can be controlled only through the diet, by special treatment, or by specific drugs. Though these facts are widely known, nevertheless patent medicines which are claimed by their manufacturers to be remedies for these diseases are sold everywhere. Aside from the fact that patent medicines are of no help in such diseases, their use results in further harm by causing the sufferer to delay consulting a doctor until he may be past medical help.



Money spent for patent medicines each year. "We are spending $500,000,000 yearly for patent medicines that do more harm than good; that is more than is paid for the services of all doctors put together."[1] In what ways may patent medicines do more harm than good?

Narcotics. The term *drug addict* is fairly familiar and is commonly used to indicate a person who has formed the terrible habit of taking morphine, opium, cocaine, heroin, or hashish (*Cannabis indica*, or Indian hemp). These drugs are habit-forming, as are also alpha-eucaine, beta-eucaine, chloral hydrate, and acetanilide. Some of these drugs have a valuable use in medicine and surgery, since they relieve pain and reduce its effects upon the system. All, however, are to some extent poisonous to protoplasm, since they prevent cells, especially those of the nervous system, from carrying on their normal functions.

Recently the use of marijuana in cigarettes and as a powder in candy or in drinks has become a serious problem. This drug is made from a certain species of a common plant (*Cannabis*), as is hashish.

Our knowledge of the effects of marijuana on man is not complete. It is known, however, that small quantities of this drug act as a stimulant. Larger quantities are definitely poisonous. A person under the influence of marijuana loses his natural restraint and judgment, and possesses a false sense of courage. There is increasing evidence that the use of marijuana has led many persons to commit serious crimes.

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[1] W. R. P. Emerson, "Extending Our Years," *Hygeia*, December, 1938, pp. 1075–1077.

Few people would deliberately form the habit of taking any of these narcotics. Yet it is possible to acquire drug habits through taking certain patent medicines. A considerable number of remedies, sold widely in drugstores and advertised to relieve asthma, catarrh, pneumonia, coughs, croup, tuberculosis, and even eye troubles, are known to contain small quantities of one or more of these narcotics: morphine, hashish, opium, heroin. The Federal Food and Drug Act of 1906 and the Harrison Narcotic Act, passed a few years later, helped to reduce the use of narcotics in patent medicines.

A particularly dangerous group of patent medicines are those that are sold for the relief of pain and particularly as cures for headaches. Most of these contain some of the coal-tar drugs that not only become habit-forming when used over a long period but also depress the heart and injure the red blood corpuscles.

Self-test. **1.** The work of preventing diseases is rapidly becoming *less* and *less* important.

2. Corn oil or cottonseed oil is *an adulterant* of olive oil.

3. Peanut shells and sawdust added to breakfast foods are *adulterants.*

4. One may acquire a *drug habit* from the use of certain patent medicines.

HOW MAY ONE CULTIVATE GOOD MENTAL HEALTH?

Mental health. Good mental health is just as important as good physical health. You can develop good mental attitudes by attention and practice as surely as you can develop a healthy body. Everyone wants to be a happy, well-balanced person.

1. Develop good habits of work, play, rest, and sleep. Plan your daily program so that you get enough rest and sleep. When you work, really work hard. Then when you play, you can forget about work and enjoy yourself thoroughly. Plan your work as far in advance as is practical. Do not put off work that must be done. Many students spoil their week ends and vacations because they do not plan their time or because they put off doing their work until the last day. Then not only is the work not well done, but they have been worrying about it all the time they were putting off doing it. Plan your daily activities so that you will not have to hurry all the time.

2. Cultivate the habit of independence. Do not expect your family or your friends to decide everything for you. You will, of course, need to consult

Titcomb from Black Star

In what ways do hobbies, such as gardening, promote good mental health?

them on important matters. But you will develop most rapidly if you learn to think things through for yourself and to form your own opinions and plan your courses of action.

3. Learn to be cheerful. When problems arise, do your best to meet them effectively. Then try not to worry about them. Somebody has wisely said, "Most of the things about which we worry never happen."

4. Set reasonable goals for yourself. We do not all have the same abilities, and we cannot all do the same things equally well. Make a study of yourself

Galloway

Sunshine, fresh air, exercise, and fun. What conditions here promote good mental health?

to learn your good points and also your weak points. Then strive to improve yourself. But do not try to reach goals which are far beyond your natural abilities. A person with little musical talent, for example, cannot hope to become a concert musician, but he can be successful in work for which he has ability. The student who cannot do well in algebra, geometry, and physics courses is not likely to become a successful engineer, but he may find a successful career in music, art, or any one of many other callings.

5. Learn to accept defeat when you are defeated. Whenever there is com-

petition, somebody has to lose. You cannot always be the winner, and you cannot always have the things you want. Cultivate the habit of losing gracefully. Do not make excuses to yourself or to others for your failures. If you have done your best, you should be satisfied. Also, you should be willing to try again and not to give up, even though you are defeated more than once.

6. Learn to face the facts, whatever they may be. Do not get into the habit of running away from unpleasant situations. Do not put off facing whatever must be faced. If you face a problem squarely, you can usually find a solution for it.

7. Try to be friendly. All of us have good qualities which will make others like us if we give these qualities a chance to be known. Try to see the other person's good qualities. Try to find qualities of his that you can like rather than qualities that you dislike.

8. Learn to work with other people. Be generous in your attitude toward another's point of view. Try to understand why he thinks as he does and acts as he does. You may not want to pattern yourself after him, but you will be a happier person if you try to understand him and accept him as he is. Do not bear grudges.

9. Cultivate a sense of humor. The person who lacks a sense of humor is too frequently offended by the careless remarks or actions of his friends. He takes himself too seriously. If you can learn to see the funny aspects of a situation, it has lost its power to hurt you.

10. Learn to have confidence in yourself. There are some things you can do well—better perhaps than most others do them. Find out what these things are. You can then have something to contribute to any group in which you find yourself.

11. Cultivate a hobby—something you do just because you enjoy doing it. If you develop such an interest, you need never be bored, and need not be without some means of entertaining yourself. On pages 628–653 are many suggestions to help you in finding a hobby. The person who has little musical talent cannot become a good musician, but he may nevertheless derive great pleasure from playing an instrument as well as he can.

Self-test. 1. It is *possible* for everybody to do well everything he may want to do. 2. It is *possible* for everybody to find something worth while which he can do well.

Self-test on Important Biological Terms

deciduous teeth
hygiene
narcotic
patent medicine
preventative medicine
sense organ
stimulant
ventilation

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Can you name other food substitutes and adulterants than those named in this chapter?

2. In a certain meat market was a sign which read: "Our sausages contain only the purest benzoate of soda. Try them." Was the proprietor complying with the letter and the spirit of the pure food laws? Explain.

3. Good habits of posture are acquired in the same way as any other habits. One must first have a desire to improve one's posture. What further steps must one follow if the habit is to become permanent?

4. Why is it a bad habit to sit slumped down in a chair, with only the small of the back touching the chair back?

Special Reports. 1. What patent medicines now on sale in drugstores contain habit-forming drugs? Write for information to the American Medical Association, Chicago, Illinois.

2. What means were employed during the Second World War to maintain the morale (good mental health) of the men and women of our armed forces?

3. In rebuilding bombed cities in the postwar period, what opportunities will there be for improving sanitary conditions?

4. By what means and in what ways was the health of the men and women in our armed forces improved?

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Life History of the Yellow Fever Mosquito. Eastman Kodak Company, Rochester, New York.
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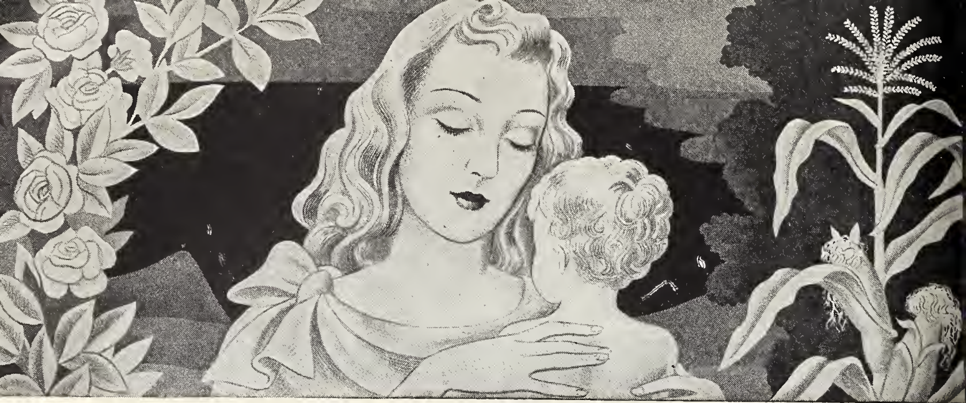
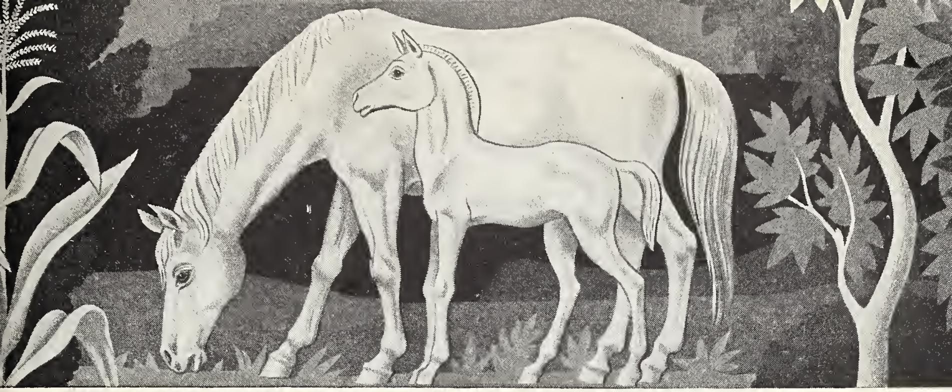


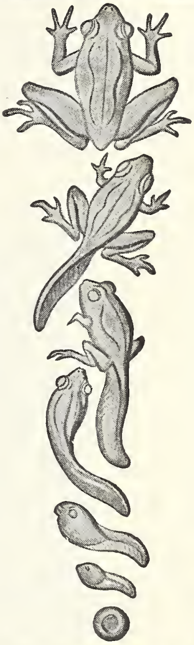
UNIT VIII · THE CONTINUANCE AND

All the world knows of the Dionne quintuplets. Thousands of visitors travel long distances just to see so remarkable a sight as five girls who were born in the same family on the same day. There are at present in this country several families which have four children of the same age, and twins are, of course, fairly common. Scientists are interested in such births because they present one aspect of reproduction and heredity.

Biologists are engaged in studying heredity and reproduction with many kinds of plants and animals. Recently one experimenter has succeeded in producing a kind of clover which is nearly always four-leaved. Another has succeeded in establishing a race of sheep which nearly



IMPROVEMENT OF LIVING THINGS



always produce either two or three lambs instead of one. A poultry man has produced a breed of hens which lay eggs having three and even four yolks each. Fruits such as the grapefruit and the loganberry were unknown when our grandparents were children. Flowers such as the double nasturtium and the "black" rose did not exist a few years ago. There are improved varieties of almost every cultivated fruit, flower, and vegetable and of almost every domestic animal.

The problems of reproduction and heredity are among the most fascinating and important in the entire field of biology. This unit is devoted to a discussion of the major questions of reproduction and heredity.

CHAPTER XXVII

The Simplest Kinds of Reproduction

Questions This Chapter Answers. 1. What were the most important steps in the overthrow of the theory of spontaneous generation? · 2. May the same kind of plant or animal use more than one method of reproduction? · 3. What is reproduction by fission? by budding? by asexual spores? by regeneration? · 4. What plants and animals illustrate each of these four methods of reproduction? · 5. What practical uses have been made of any of these methods of reproduction?

CAN LIFE START FROM DEAD MATERIAL?

Early attempts to explain life. From earliest times people have tried to account for the presence of plants and animals on the earth. Many folk tales of primitive peoples describe the sudden appearance of men, and of animals or plants which were important to those peoples. There is, for example, the famous Greek legend of the race of mighty warriors who grew at once, full sized, and completely armed and armored, from a dragon's teeth which had been sown in the ground. There are Indian tales of fish that suddenly appeared in the lakes and streams, and of buffaloes which suddenly came into being when urgently needed for food. Such legends are, of course, not scientific accounts and have never been credited by scientists.

There was, however, a belief not so very different from some of these ancient folk tales which through nearly all history was accepted by many people. This was the "theory of spontaneous generation."[1] According to this theory, under favorable circumstances dead organic material and even inorganic material may become alive of itself. The writings of noted men, many of them scientists, of ancient times and of even fairly recent times not only supported the belief in spontaneous generation but gave many examples which the writers thought proved its truth. Thus, in the fourth century before Christ, Aristotle stated that mice form and become alive from old rags that have been packed in boxes and placed in dark warm places. About nineteen hundred years later Van Helmont published instructions for producing scorpions and mice spontaneously. Also, at about this time, Alexander Ross wrote thus about Sir Thomas Browne, who had expressed doubt about whether "butterflies, locusts, grasshoppers, shellfish, snails, eels, and such like" are produced from decaying matter: "To question this is to question reason, sense, and experience. If he doubts this, let him go to Egypt, and there he will find the fields swarming with mice begot of the mud of the Nile, to the great calamity

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[1] *Spontaneous* (spŏn tā′nē ŭs): beginning or continuing without outside influence or help. *Generate* (jĕn′ẽr āt): to begin or to produce. *Generation* (jĕn ẽr ā′shŭn): the process of generating or producing something; usually refers to producing new plants and animals.

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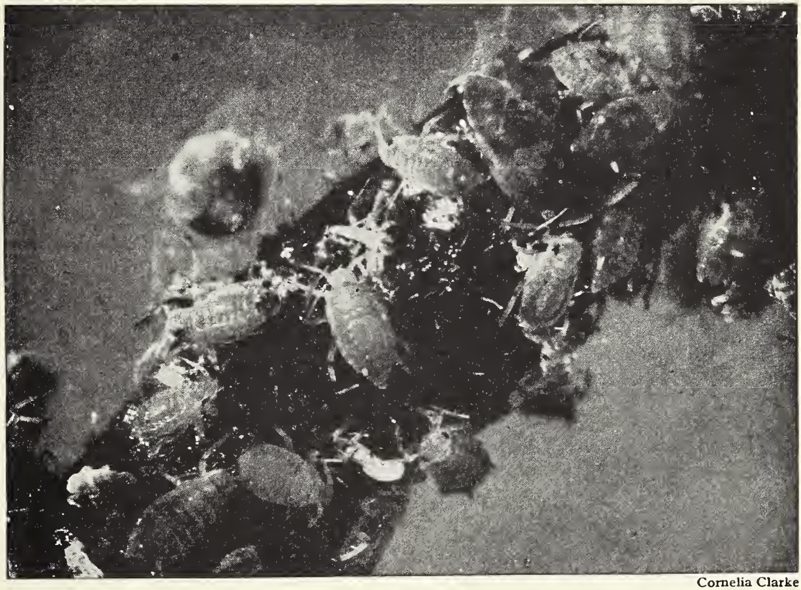
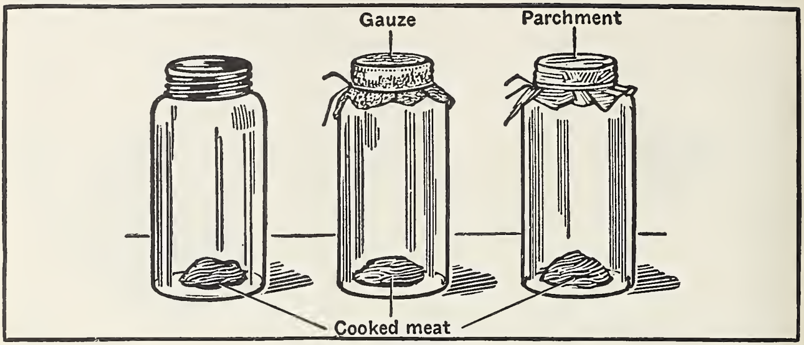
Toads and frogs were once supposed to originate, under the influence of sunshine, directly from the mud in the bottoms of ponds. What other such unfounded beliefs have you heard? (The toad at the right is croaking)



Cornelia Clarke

Plant lice on a stem (greatly enlarged). Aristotle taught as an observed fact that plant lice come from dew. Can you explain how someone might make this inaccurate observation?



Redi's experiment. **Exercise on Scientific Method (Using Controls):** Which of these jars served as controls? Explain

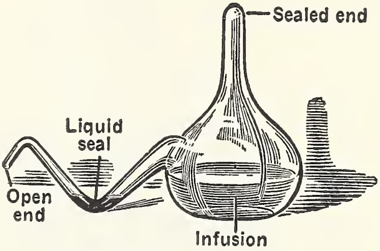
of the inhabitants." More than a century later Buffon said that worms may be caused to develop spontaneously by putting together the hollow sides of two pieces of building brick, provided crushed wood and oil have been placed first in one of the hollows of the brick.

Until a few decades ago it was not uncommon for people who saw mosquitoes and other insects arising from the surface of stagnant water to cite these observations as illustrations of spontaneous generation of living things. During the childhood of many persons now living the belief was common that the living things which cause spoiling and decay in such liquids as sirups, soups, and the water of stagnant pools are developed by spontaneous generation. In fact, it was generally believed, and still is in some countries, that any organic matter which has favorable temperature and proper moisture may be the scene of spontaneous generation of living things.

Redi's famous experiment. The first important step toward the overthrow of the theory of spontaneous generation resulted in the seventeenth century from experiments by Redi, an Italian scientist. Redi doubted the common claim that fly larvae are spontaneously produced in meat. His theory was that the larvae develop in meat only if flies are allowed to come in contact with it. It must be remembered that the life history of flies was not then known.

To test his theory Redi invented this experiment: He first cooked meat in order to be certain that nothing remained alive in it. He then placed some pieces in each of three jars. One he left uncovered, one he covered with gauze, and the third with parchment. Flies could enter only the first jar. Later, larvae, or maggots, appeared in the meat in that jar. Flies laid their eggs on the gauze cover of the second jar, where they hatched into maggots. The meat became rotten in both covered jars, but no maggots appeared in them.

Redi's experiment proved (1) that, in so far as meat is concerned, larvae do not generate in it spontaneously and (2) that reproduction of flies depends on the laying of eggs by parent flies. It also stimulated studies of the life cycles of insects. But the most important result was the contribution of evidence which helped to show that new living things come only from those already living.



Pasteur's flask. In what respects did this experiment mark an improvement over the experiment by Redi?

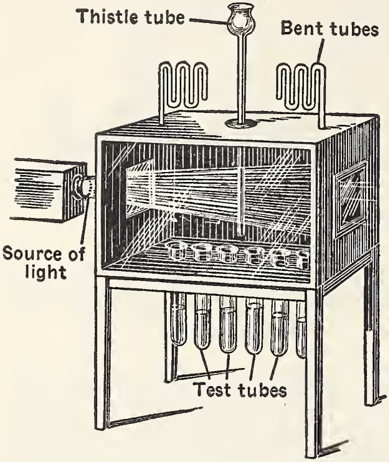
Pasteur and spontaneous generation. Redi's experiments did not, however, result in the overthrow of the theory of spontaneous generation. During the next two centuries the controversy continued. From time to time noted scientists performed experiments, the results of which they interpreted as favoring one side of the controversy or the other. The invention of the microscope, the discovery of oxygen, the discovery of the causes of fermentation, and other scientific discoveries helped to produce new evidence. In the great mass of evidence produced, however, the contributions of two men, Pasteur and Tyndall, deserve special mention.

A number of experiments by various men seemed to prove that infusions[1] in which all living organisms have been killed by heating remain unspoiled if no air is admitted to them. Yet such experiments did not remove all the objections raised by the critics. Pasteur therefore designed a special flask, with two necks, one of which was curved and had a small opening. He put an infusion into the flask, sealed the larger opening, and boiled the infusion. Thus all living things in the infusion and the flask were killed. Moreover, no dust could then enter the flask and reach the infusion, because it would either settle on the surface of the curved neck or would be stopped by the liquid in the curve.

No microscopic life developed in the liquids so treated. Pasteur therefore claimed that his experiment proved the theory of spontaneous generation to be false. Some of the chemists objected, however, that boiling had caused changes in the infusions, with the result that after being boiled they would no longer support life. Pasteur then broke open the mouths of some of his special flasks in which there were infusions that had been sterilized by being boiled. Thus he permitted air to enter. Soon the liquid became filled with

[1] *Infusion* (ĭn fū'zhŭn): liquid in which meat or other substances out of which organic matter can be dissolved have been steeped.

microscopic living things. This result proved that, after having been exposed to the air, the boiled liquids would support life. But, more important than that, it proved that the living things came in with the air that entered the broken flasks.



Tyndall's apparatus. The box was entirely closed, and the inside was coated with glycerin to catch dust particles as they settled. A light which flashed through the windows indicated when all dust had settled. Air could enter the box only through the bent tubes, which caught the dust in their bends. The infusions, which were poured through the thistle tube into the test tubes, were boiled by placing a pan of boiling oil below so that the tubes extended into boiling oil. No life developed in any of the tubes. Later, however, when Tyndall removed the test tubes and exposed their contents to the outside air, all the infusions soon spoiled. How did this last step in the experiment serve as a control?

Experiment 60. What results will you obtain from repeating some of the early experiments with infusions? Prepare an infusion made of water and beef, dried grass, any packing material, or commercial beef broth. Sterilize the liquid by boiling it for ten minutes. Then place a small amount of the liquid in each of eight flasks or large test tubes. Keep half of the flasks or tubes closed with plugs of cotton which has been sterilized. Place one open and one closed tube side by side for twenty minutes in the school hallway. Place another pair out of doors and a third pair in the schoolroom. Dip your lead pencil into the liquid in the open tube of a fourth pair. Mark the open flasks so that you can readily identify them; then plug all the flasks with cotton and keep them in a warm dark place. After two or three days examine the pairs of tubes. What difference do you find between the infusions in the tubes which have been kept plugged and those which were opened? Do these results agree with the evidence of Redi and Pasteur? Explain.

What were the controls in the four parts of this experiment? Why were they necessary?

Pasteur's experiments thus added important evidence against spontaneous generation and in favor of the claim that new life, even among microscopic forms, comes from life that already exists. These and other experiments[1] also proved that the air may be a means of carrying the smallest kinds of living things into infusions or other food materials.

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[1] Pasteur later found that an ordinary glass flask or a test tube, when closed by a cotton plug, made a satisfactory substitute for the special flask he had used in his earlier experiments. The cotton plug keeps out the dust and small organisms carried by the air, yet allows the passage of oxygen and other gases.

Tyndall's experiments. John Tyndall, an English scientist (1820–1893), experimented further on spontaneous generation. He constructed an apparatus by means of which to make sure whether in Pasteur's experiments the air carried the living things into the infusion, as Pasteur and his associates asserted, or whether they were formed and came to life within the infusion, as Needham (another English scientist) and his followers maintained. Tyndall's apparatus made it possible (1) to take out of the air all dust particles and therefore all living things; (2) to allow this dust-free air to reach the infusion in open test tubes; (3) to observe the infusion from day to day without handling it.

Tyndall announced in 1876 that no living things developed in the infusion that was tested in this new apparatus. His evidence was sufficient to complete the overthrow of the theory of spontaneous generation. All scientists now accept the biological principle that life is produced from life, that is, that living things are produced only by other similar living things.

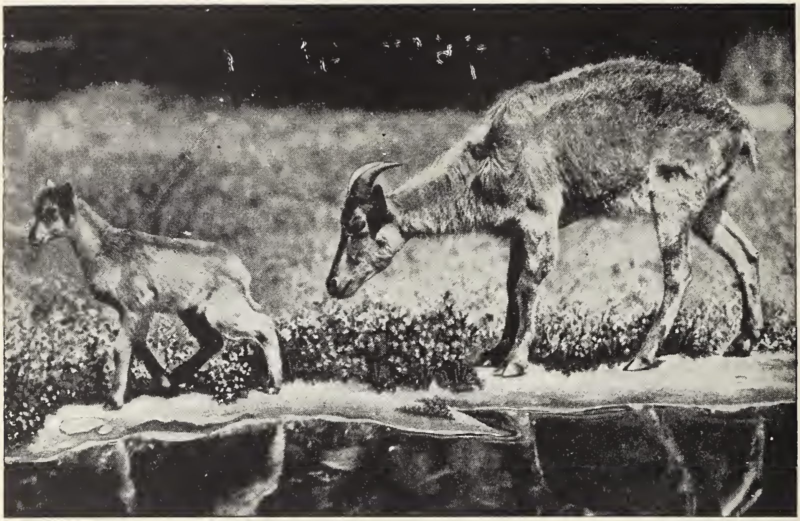
We are not likely to estimate too highly the importance of the experiments by Tyndall, Pasteur, and others, not only because of the facts and principles established by them, but also because of the demonstration they provided of the use of the scientific method in solving problems. One immediate result was Lister's proof that infection of surgical wounds can be prevented.

With the claims of spontaneous generation disproved, a new and strong stimulus was given to efforts to learn just how living things are reproduced. Much was then known about reproduction among some of the higher plants and animals. But not much was known about the life cycles of lower forms of life. Even today the life cycles of many living things are unknown.

Self-test. 1. The theory that living things come alive out of inorganic materials is called the theory of *spontaneous generation.*

2. One difficulty which the early experimenters on spontaneous generation encountered was (1) in keeping dust out of the infusion; (2) in killing the living things already in the materials from which the infusion was made; (3) in the proper use of the microscope; (4) in learning the life histories of insects; (5) in properly closing their flasks with cotton.

3. Select from the following list the names of the scientists who were prominent in disproving the theory of spontaneous generation: (1) Aristotle; (2) Tyndall; (3) Burbank; (4) Edison; (5) Pasteur; (6) Ross; (7) Browne; (8) Buffon; (9) Van Helmont; (10) Redi; (11) Lister; (12) Needham.



Newton H. Hartman

Mother goat and kid. By what processes will the kid finally attain the size of the mother?

HOW DO PLANTS AND ANIMALS REPRODUCE?

Growth and reproduction. It is a matter of common knowledge that living things are small when they begin their life. It is an interesting fact, however, that the young animals of one kind are usually of about the same size; also that fully grown animals of the same kind are of about the same size. For every adult organism there is a "most successful size." Thus, if squirrels had the size of elephants, they could not live as squirrels do. To be a successful animal, that is, to survive and reproduce, an animal must not vary too greatly from the average size of its kind.

The nonliving material which animals take in as food is changed by the protoplasm of their bodies into living protoplasm. New cells and new tissues are formed. It is by this process of growth that living things increase in size or add new parts to their bodies.

When growth has continued long enough for the organism to become mature, reproduction may occur. In the process of reproduction some part of the living body is separated and leaves the parent body on which or within which it has developed. It may then begin to develop into a new individual. There is no reproduction unless some portion of a living organism is able to leave its parent's body and to live independently.

Kinds of reproduction. There are several kinds of reproduction. One type is illustrated by such a plant as strawberry, blackberry, or rose. When a branch of such a plant is in contact with the ground for a long time, it may develop roots, a new stem, and leaves. Thus a new plant starts directly from a part of the old plant. Another type of reproduction is illustrated by many of the simple plants and animals which produce special cells called spores. Each of these spores may of itself grow and become a new plant.

*Such methods of reproduction, in which only one plant or animal is needed to produce a new organism, are known as *asexual reproduction.* In many plants and animals there are separate sexes. Each sex produces cells which take part in reproduction. When two separately formed cells unite to form a new plant or animal, the process is called *sexual reproduction.* Thus, asexual reproduction is reproduction without the union of reproductive cells, and sexual reproduction is reproduction by the union of reproductive cells.

Asexual reproduction is the older, more primitive method of reproduction. This method is more common in the lower, more primitive organisms. However, occasional examples of asexual reproduction are found as high in the scale of animal life as the insects. The larva of a gall gnat, for example, and the pupa of a midge can lay eggs which will hatch and finally develop into adults. These insects also reproduce sexually in the adult stage.

Like these insects many of the simpler organisms reproduce both asexually and sexually. Many of the plants and many of the lower animals have more than one method of asexual reproduction. But sexual reproduction is the only method found among the chordates.

The remainder of this chapter will discuss chiefly four methods of asexual reproduction in plants and animals. These four methods are reproduction (1) by fission, (2) by budding, (3) by asexual-spore formation, and (4) by vegetative reproduction.

Self-test. 1. When a portion of an organism separates from the parent's body and begins life for itself, *reproduction* is said to have taken place.

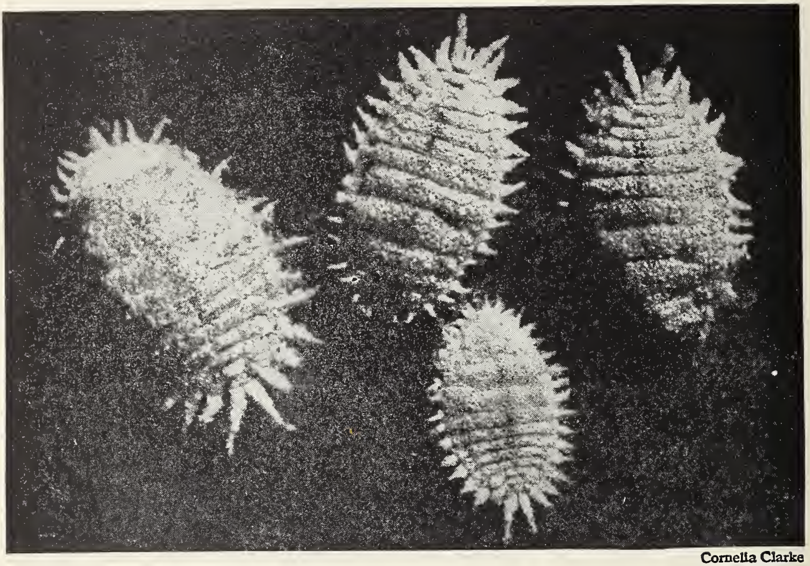
2. More of the simpler animals and plants reproduce by *sexual* than by *asexual* means.

3. *No* animals reproduce asexually.

4. Asexual reproduction may begin with *one cell.*

5. Sexual reproduction is possible only when *many* cells unite.

6. *Asexual* reproduction is only possible with *two* organisms.



Cornelia Clarke

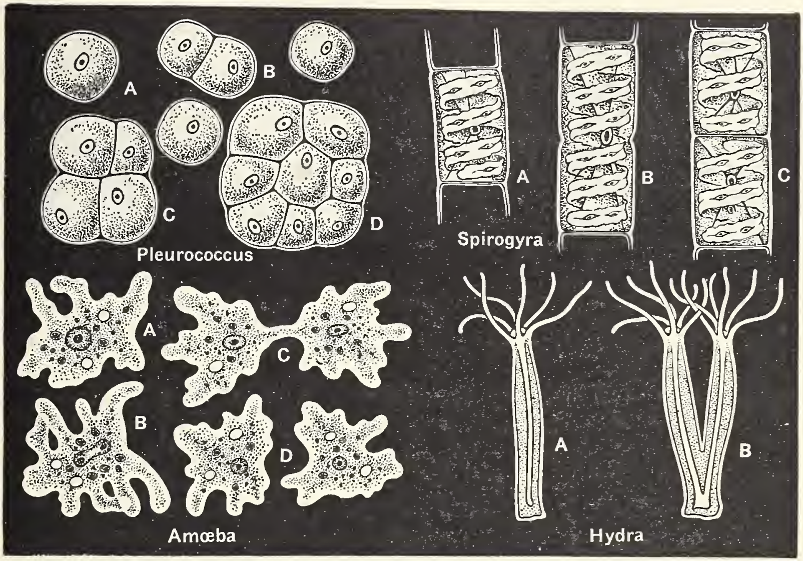
Mealy bugs (enlarged). Some scales and plant lice usually reproduce asexually. How does this characteristic make them harder to get rid of as plant pests?

HOW DO PLANTS AND ANIMALS REPRODUCE BY FISSION AND BY BUDDING?

Reproduction by fission. *The simplest method of reproduction is by the process called fission. In this process the organism divides into two parts. The simplest one-celled plants, such as the bacteria, reproduce by this method only. When a bacterium has reached its full size, it may divide into two bacteria. The cell divides at the middle into two cells. Thus part of the original protoplasm is in each new cell. If conditions are favorable, each new cell rapidly grows to the size of the parent cell. Soon it is ready to divide again.

Each new bacterium carries on its life activities independently of the other half of its former self. In a sense these two new cells are still parts of the single parent cell. Succeeding cells are likewise partly old and partly new, since part of the parent's body becomes directly a part of the body of the offspring. Plants and animals which reproduce by fission may starve to death or be killed by high temperatures or other severe conditions, but they never die of old age. They continue to reproduce indefinitely while their living conditions remain favorable.

In some plants, as *Pleurococcus*, the cells formed by fission do not entirely



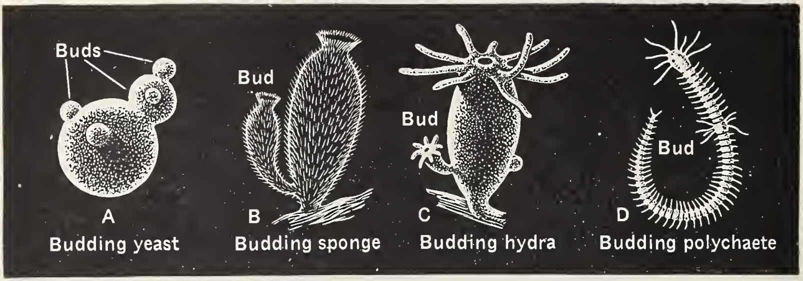
Reproduction by fission. Can you explain all four parts of this figure? Can you explain why bacteria are often found attached together in chains? What do you understand to be meant by the conditions which would be favorable to fission?

separate. Also, *Spirogyra* consists of long threads, or strands, which are made up sometimes of hundreds of cells joined end to end. The strands grow in length as the separate cells reproduce independently by fission.

The Protozoa (*Amoeba*) reproduce by simple fission. This method of reproduction, moreover, is found in animals as high in the scale of life as *Hydra*, and even in some of the flatworms. Most animals which reproduce by fission reproduce also by other means, as will be shown later.

Reproduction by budding. *A somewhat different method of asexual reproduction, called budding, occurs with yeast plants and with some simple animals. Instead of the protoplasm of a whole yeast cell dividing into halves, a bud is formed on one side of the cell. This bud is at first very small, but it enlarges rapidly. The nucleus of the old cell divides, and one of the divisions passes into the developing bud. After a while a wall forms so as to separate the bud from its parent cell. It may soon become free and proceed to grow until it reaches adult size.

Sometimes a bud will develop a second or third bud before the first is free from its parent cell. When this occurs, a small chain of yeast cells may be found. But each cell is really a new plant; when set free, it can live alone.



Reproduction by budding in simple plants and animals. Compare the process of reproduction by budding with that by fission

Many of the Protozoa, the sponges, and such coelenterates as *Hydra* reproduce by budding as well as by several other methods. Occasionally examples of budding are found among animals as high in the scale of life as the annelids (polychaetes).

Budding differs from simple fission in the relative size of the offspring produced. With fission the two individuals formed are of the same size and are similar in every way. In budding the new individuals are always smaller than the parent. Moreover, in fission the parent cell disappears. All its parts appear in the two "daughter" cells. In budding, however, the parent organism continues to live.

Self-test. 1. In fission *one* of the resulting organisms is older than the other.

2. The method of reproduction by which a simple animal divides into two complete animals is called *budding.*

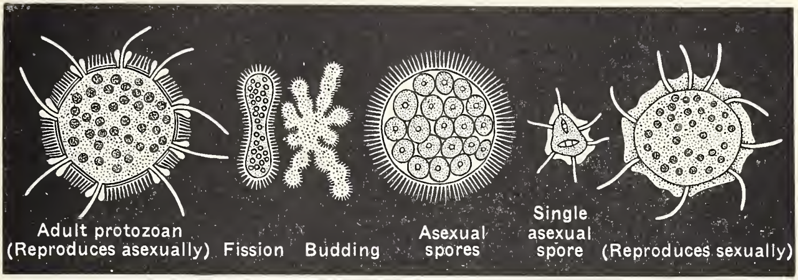
3. In *fission* the new cell is smaller than the parent cell.

4. In *budding* the newly formed cells are of equal size.

5. *Few* chordates reproduce by budding or fission.

HOW DO PLANTS AND ANIMALS REPRODUCE BY MEANS OF SPORES?

Reproduction of plants by asexual spores. The formation of resting spores by bacteria, Protozoa, and other simple organisms has already been mentioned. Such spore formation occurs when there are unfavorable living conditions, such as extreme cold, heat, or dryness. The protoplasm contracts in the middle of the cell, and the cell wall becomes thicker. Sometimes an inner heavy wall is formed close to the condensed protoplasm. In this condition the cell may remain dormant, or inactive, for months or even years.



This protozoan (*Trichosphaerium sieboldii*) reproduces by simple fission, by budding, and also by asexual spore formation. When the asexual spores escape from the cell, they look like the single asexual spore shown here, and develop into the form shown at the right. This form reproduces again by fission and by budding, and finally reproduces by a sexual method which is not yet fully understood. Each animal formed by this last process develops into an animal like the first form. Thus the cycle is completed. How many methods of reproduction does this animal have?

This method of forming spores is an important adaptation for survival. It is not, however, a true method of reproduction, because no part of the organism splits off and carries on life independently. No new individuals are formed. There are, however, true methods of reproduction by spores among practically all the algae and fungi and also among many of the Protozoa.

An example of reproduction by asexual-spore formation is furnished by yeast. During this process the wall of the plant becomes thicker. The protoplasm within divides into two masses, then into four, and finally into eight. If living conditions are unfavorable, it may pass through a period of quiet with the eight cells, or spores, held by the old cell wall. Finally the old cell wall dissolves and sets the spore cells free. Each one grows as a new yeast plant. Each reproduces again by the more common method of budding, although some of its descendants may later form spores.

Reproduction of animals by asexual spores. Of the Protozoa which reproduce by spores, *Amoeba* is most familiar. One of these animals contracts into a ball and surrounds itself with a three-layered wall (sometimes called a cyst). The nucleus then divides, first into two parts, then into four, and so on until as many as five hundred to six hundred daughter nuclei may be thus produced. Each small daughter nucleus then becomes surrounded by a wall and thus becomes a spore. The old cell wall finally breaks, releasing the hundreds of spores. In about three weeks under favorable life conditions the new individuals of *Amoeba* have grown and developed to look like their parent. If conditions are favorable, these mature amoebae will reproduce by fission, which is the commoner method by which this animal reproduces. Reproduction of *Amoeba* by the formation of asexual spores is relatively rare. Some of the other Protozoa—for example, the protozoan which causes malaria—may reproduce by spore formation. (See the figure on page 553.)

Self-test. 1. New individuals develop from *all* spores.

2. When spores *germinate,* one cell develops finally into *two* new cells.

3. In asexual reproduction by spores the spores divide always into an *odd* number of new cells.

4. In asexual reproduction by spores *one* of the resulting cells is older than any of the others.

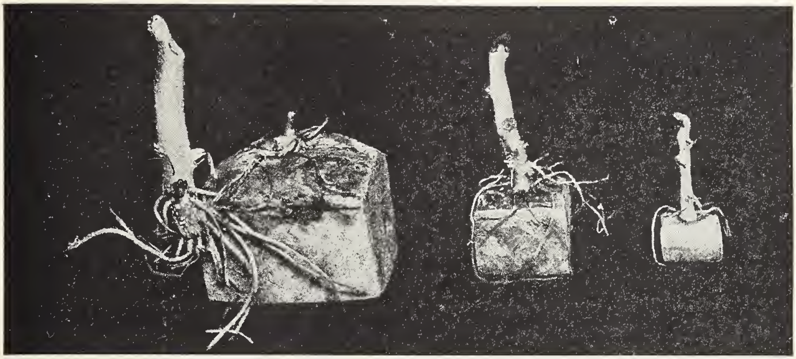
HOW DO PLANTS AND ANIMALS REPRODUCE VEGETATIVELY?

Vegetative reproduction of plants. *Some very simple plants, as well as many of the higher ones, are able to reproduce asexually by growing a complete plant from a part of the parent plant. This process is vegetative reproduction. As was stated earlier in this chapter, many kinds of higher plants will grow new roots at points where a branch remains in contact with the soil. After these roots have become well established, the branch which connects them with the old plant dies, and an entirely new plant is formed. By this means such plants reproduce and spread in the neighborhood of the parent plants. In such vegetative reproduction the old individual merely has one of its growing parts "strike out for itself" as a new individual. Stems which thus run along are called runners (stolons). Such reproduction, in which a part of the organism grows and produces other parts, is called *regeneration.*

Vegetative reproduction of plants from cuttings. If willow twigs are placed with the ends in water for a few weeks, roots usually develop at joints in the twigs. Such rooted twigs will grow if planted out of doors in good soil and if kept well watered. This is merely an artificial way of causing the willows to reproduce by regeneration. Many other woody plants may be caused to reproduce in this way. This method of reproduction has long been used by men in propagating the plants which they found useful.

Plants such as geraniums, coleus, salvia, grapes, roses, sugar cane, and bamboo may be reproduced by cuttings. If they are placed in sand and kept with favorable temperature, light, and moisture, they soon produce roots and may then be planted wherever it is desired to have them grow. An especially desirable individual plant may be multiplied by this means into a very large number of new plants.

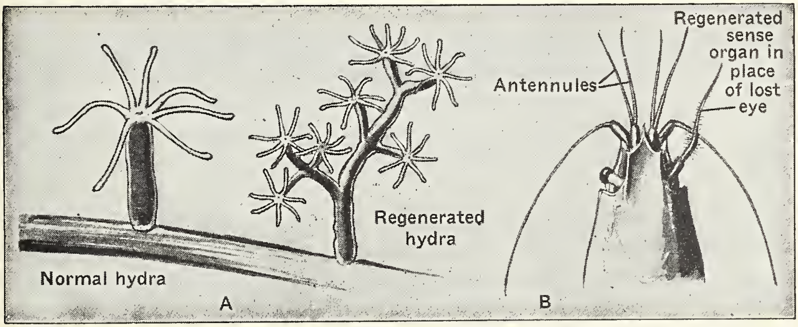
A special kind of cutting is used in growing the common white potato. The tuber, which is really a stem, has a few buds commonly called eyes. It



Potato plants grown under identical conditions. How do you account for the difference in size of the young plants? **Exercise on Scientific Method (Using Controls):** How is each a control for the other two?

is so cut that each piece, or cutting, has one or more buds. When these cuttings are planted, roots, stems, and leaves are regenerated from the buds. Finally, short new underground stems (rhizomes) grow, and the new potatoes are formed at the ends of these short stems.

Vegetative reproduction of animals from cuttings. While experimenting with *Hydra* about two centuries ago, the French scientist Trembley made the astonishing discovery that if the animal were cut into two, three, or even four pieces each part would develop into a complete new animal. These experiments furnished the first knowledge that there is regeneration of animals from pieces, similar to regeneration of plants from cuttings.



Can you explain how this seven-headed hydra, in A, might have been produced? The antenna-like organ of the crayfish, in B, illustrates the fact that a regenerated member is not always like the member it replaces

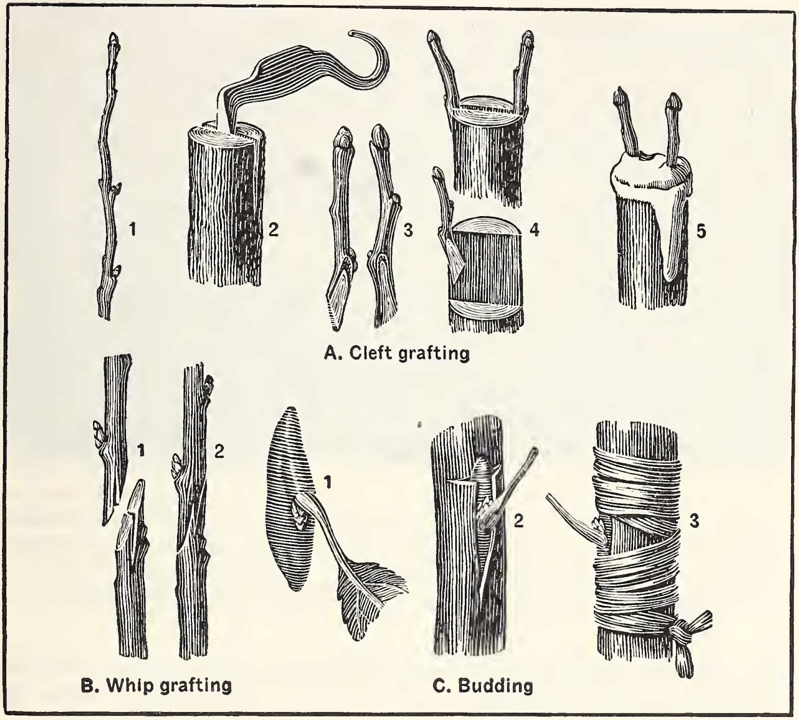
National Parks Bureau of Canada

The deer and its close relatives the moose and the elk lose their horns and regenerate new ones every year. Can you name other structures which man, other mammals, or birds can regenerate if lost?

The ability of sponges to regenerate from cuttings has now been put to commercial use. Sponge cuttings about an inch square are put on small metal disks placed upon stakes or wire fences that are weighted down in shallow water. When the new animals have developed to the desired size, they can be more easily "harvested" than when they grow naturally.

Flatworms and starfish, like hydras and sponges, will develop complete new animals from relatively small portions. The earthworm will usually grow a tail behind a severed head end, but cannot grow a head on the tail part.

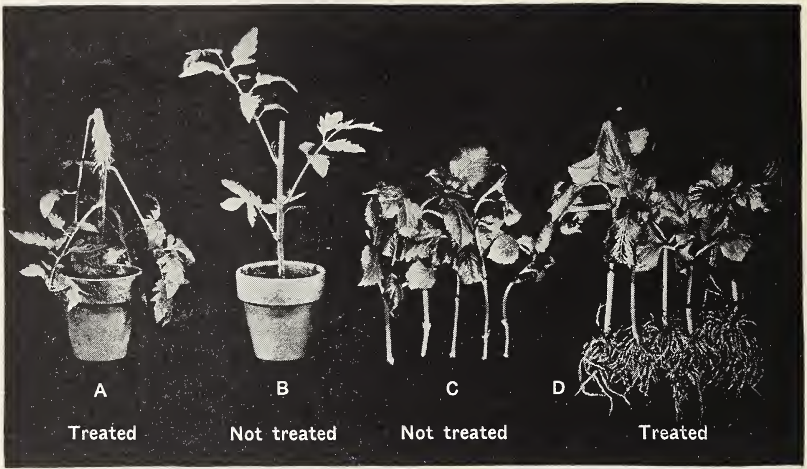
While experimenting with *Hydra*, Trembley found that if he split the head and then separated the parts somewhat, each portion would regenerate the rest. The seven-headed hydra (p. 555) was produced in this way. Many animals are able to regenerate lost parts. Only fairly primitive animals, however, are able to reproduce by regeneration. Thus an arthropod—for example, a spider or one of the crustaceans—will die if a vital organ or section of its body is removed, but it can regenerate a new leg or other appendage.



A, cleft grafting; B, whip grafting; C, budding. Use the diagrams to explain these terms

The vertebrates have limited powers of regeneration. Some Amphibia can grow new limbs and tails. Few of the reptiles are able to regenerate missing members, though some lizards—for example, the swift and the glass snake—can regenerate new tails. These tails, however, are not like the original tails, since they contain no vertebrae. Regeneration in animals of the two highest phyla, the birds and the mammals, consists only in the repair of broken bones, the healing of wounds, and also the replacement of a few special structures, such as feathers, hair, and, in some cases, horns. The young animals of every kind have considerably greater powers of regenerating lost or injured structures than the old individuals of the same species.

Vegetative reproduction of plants by grafting. *It has long been the practice to grow apples, peaches, oranges, grapefruit, English walnuts, roses, and many other fruit and flowering plants from cuttings taken from the plants



Boyce Thompson Institute of Plant Research

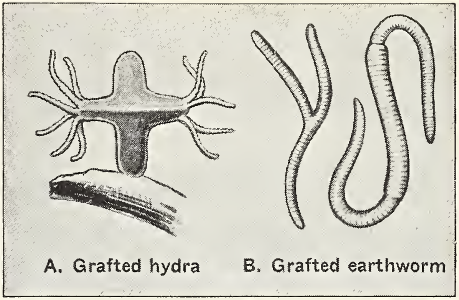
A and B are two tomato plants with tops removed. Plant A was treated on the cut surface with chemicals (lanolin preparation of naphthalene-acetic acid). C and D are dahlia cuttings. The cut ends of the stems in D were treated with chemicals (indole butyric acid). Note the roots which have developed on the cut ends of A and D. **Exercise on Scientific Method (Using Controls):** Which are the controls in this experiment?

known to produce the best fruit or the best flowers. These cuttings, however, are not planted in the ground. Instead they are made to grow upon the branches or stems of other plants.

First a branch or a stem containing a bud is cut from the desired plant. This cutting must then be so fastened into the cut surface of the branch or stem on which it is to be grown that the growing cells of the cutting (scion) come in contact with the growing cells of the old stem. Thus the cambium tissues of the new branch and of the old stem grow together. By having the same kinds of cells united, the soil water passes upward through the xylem to the top of the cutting. Likewise the food that is later manufactured by the leaves of the cutting passes downward through the phloem into the roots of the plant.

The character of a cutting does not change as a result of grafting. Grafting is therefore a means of making widely available and permanent the most desirable kinds of flowers, fruits, nuts, or foliage. For example, the navel-orange trees have all been produced directly or indirectly from one parent tree.

Often the cutting of the desired plant may be grafted upon the root of some especially vigorous but otherwise less desirable plant. Thus apple twigs or buds can be made to grow and produce good apples if they are grafted upon the sturdy stems of wild hawthorn trees. The most beautiful and highly specialized roses may be grown upon strong but ordinary rosebushes. English walnuts are commonly produced by grafting cuttings from English-walnut trees upon the stems of black-walnut trees. The Koster spruce, an especially beautiful blue spruce, is reproduced by grafting small branches of it upon the roots and stems of other spruces which do not possess the desired blue foliage.



This double-headed hydra resulted from grafting part of one hydra on another. Can you suggest how these odd-looking earthworms were produced? (After Hegner)

New methods of plant production. Recent investigations indicate the value of a new method by which cuttings of many kinds of woody plants, as well as common house and garden plants, may be caused to take root and begin to grow without being either planted in the ground or grafted upon other plants. The cuttings are first treated with certain chemicals and are then kept in moist and warm places. Roots develop, and soon each cutting may be planted in the soil. This chemical treatment of plant cuttings gives good promise of becoming a common method of plant propagation. There is some evidence indicating that the chemicals used also stimulate the plants to make more rapid growth than do cuttings used as grafts upon other plant stems.

The proper care of young cuttings. Those who have grown such plants as geraniums, coleus, and salvia from cuttings know that constant care must be given to prevent changes in temperature, moisture, and light. Too much or too little light or moisture, or too high or too low temperature, kills the cuttings. Too much moisture and heat may favor growth of destructive diseases. It has been found that gases (illuminating gas and certain others) in the air may prevent growth.

Reproduction of animals by grafting. Experiments have shown that grafts similar to those made with plants can be successfully made with some of the lower animals. Strange and complete new creatures have thus been produced with the hydras, the flatworms, and even animals as complex as earthworms. Certain kinds of grafts, moreover, can be successfully made upon higher animals, provided such grafts require the animals only to regenerate, or heal, wounds or injured bones. A striking case was that of grafting a horn in the top of a calf's head; and another, that of exchanging the spurs and the comb of a young rooster.

Knowledge of the principle of regeneration in higher animals is often applied in modern surgery. For example, skin taken from the thighs and grafted upon wounds caused by burning has frequently saved the lives of persons who have suffered serious burns. Recently, also, when a man had lost a finger, a surgeon made him a fairly useful new finger. This was done by first grafting upon the severed bone a piece of bone taken from the patient's shin. A piece of flesh taken from the patient's abdomen was then molded round this bone. Not only did the bone from the shin grow to the finger stump and the flesh from the abdomen grow round this piece of shin-bone, but the wounds made in the shin and the abdomen also regenerated, or healed. Another surgeon successfully grafted into one patient's arm a four-inch section of nerve which he took from another patient's leg which had been cut off. Doubtless still further uses of grafting will develop as medical science, particularly surgery, advances.

Self-test. 1. Reproduction of plants from cuttings is an example of *generation.*

2. The "eyes" of a white potato are *buds* from which new potatoes grow.

3. Regeneration of complete animals from a part is possible with animals as high in the scale of life as *mollusks.*

4. Regeneration of new legs of an animal is possible with animals as high in the scale of life as the *arthropods.*

5. Regeneration of broken bones and wounds is possible with animals as high in the scale of life as *the fishes.*

6. In grafting, plants may be grown upon the *roots* of other kinds of plants.

7. Successful grafting has been practiced with animals as high in the scale of life as the *birds.*

Self-test on Mastery of Facts. Summarize all the ways in which the four methods of reproduction described in this chapter are alike and are different.

Self-test on Important Biological Terms

asexual reproduction
budding
fission
grafting
infusion
regeneration
reproduction
sexual reproduction
spontaneous generation
vegetative reproduction

Self-test on Fundamental Generalizations. 1. What evidence can you state from the first section of this chapter which tends to support these principles?

Man's ideas of what is true change as more facts are learned.
Scientific knowledge grows slowly.
Scientific truth is built up by means of many small additions.
Scientific progress is not always steadily forward.

2. Regeneration is of great value to organisms in survival. Can you explain this principle?

3. What evidence can you cite from this chapter to support the principle that "life springs only from life"?

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. In accordance with the statement in this chapter, name in the order of increasing complexity the classes of chordates which reproduce sexually only. Name in the order of increasing complexity all the animal phyla representatives of which may reproduce both sexually and asexually.

2. When conditions are most favorable, bacteria may divide as often as once every fifteen minutes. It has been estimated that if conditions remained favorable, there would be 281,474,976,710,656 bacteria resulting from a single bacterium in twelve hours. These bacteria would make a solid sphere about four inches in diameter. In a relatively short time, if all conditions remained favorable, there would be a ball of bacteria the size of the earth. List as many reasons as you can to explain why the bacteria are prevented from producing at their maximum rate.

3. Reproduction by spore formation, as in the yeast plant, is closely related to reproduction by fission. Compare these two methods of asexual reproduction for ways in which they are similar and for ways in which they are different (see "How to Study," p. x).

4. Contrast the process of budding with that of spore formation.

5. Could one produce a new kind of apple by grafting a branch of a Baldwin apple tree to a Northern Spy tree? Explain.

Exercise on Scientific Attitudes. Which of the scientific attitudes (listed on page 624) are illustrated by various incidents in the story of the overthrow of the theory of spontaneous generation? In each case state the evidence or the incident which relates to the scientific attitude.

Exercise on Scientific Method. 1. *Making Inferences and Inventing Experiments.* At one time oyster-growers tried to rid oyster beds of starfish by cutting the starfish in two. A man would arm himself with a pole to the end of which a knife was attached. When he came upon a starfish, he hacked it in two with the knife. But instead of exterminating the starfish by this method, the growers soon found these animals more numerous than before. How do you account for this fact? Can you propose a method which might prove more effective in getting rid of starfish?

2. *Making Inferences.* Can you suggest a reason to explain why an apple twig cannot be successfully grafted to an oak tree?

3. *Making Inferences.* While on a camping trip, a man made a clothesline by fastening the ends of a wire around two near-by trees. When he "broke camp," he cut off the wire close to both trees, leaving the ends of the wire around them. Upon returning to the spot a few years later, he found that only the ends of the wire were visible, sticking out of the trees. How would you explain this fact?

Project 24. To use regeneration as a means of growing new plants. Secure cuttings from various house plants, such as those mentioned, cactus plants, and others. Place the ends in moist soil and keep the soil moist for all the cuttings except those of the cactus. Put these in sandy soil and dampen the soil only about once a week. Vary the conditions of moisture and the kinds of soil with different cuttings from the same kinds of plants. Keep a record of the plants with which you succeed in securing healthy plants and of those with which you fail.

Special Reports. 1. What did Leeuwenhoek and others besides those named in this discussion contribute to the overthrow of the theory of spontaneous generation? (This topic is usually listed in the encyclopedias under the name *abiogenesis.*) How was the theory modified after the invention of the microscope? What were the various steps in Lister's experiments to determine how infections could be prevented in surgical operations?

2. Find in an encyclopedia or in an advanced textbook of zoology an account of the method of asexual reproduction called gemmulation. How does this method differ from that of ordinary spore formation?

3. Look up *heteromorphosis* in an encyclopedia for other examples of regeneration in which the new part is not like the one it replaces.

4. Look up *regeneration* in an encyclopedia, for further examples.

5. From a study of garden manuals and seed catalogues, make a list of garden plants that reproduce (*a*) from cuttings, and (*b*) from runners. Can you discover any wild plants that reproduce in these ways?

6. Consult encyclopedias and textbooks of botany and zoology for other examples than those given on page 552 of animals that can reproduce by budding.

7. From a surgeon find out how regeneration is brought about by grafting skin and bone tissues.

8. Find in textbooks of zoology and botany, in "big" dictionaries and encyclopedias, and in such books as Wells, Huxley, and Wells's *The Science of Life* examples of plant and animal regeneration on which to make a class report.

CHAPTER XXVIII

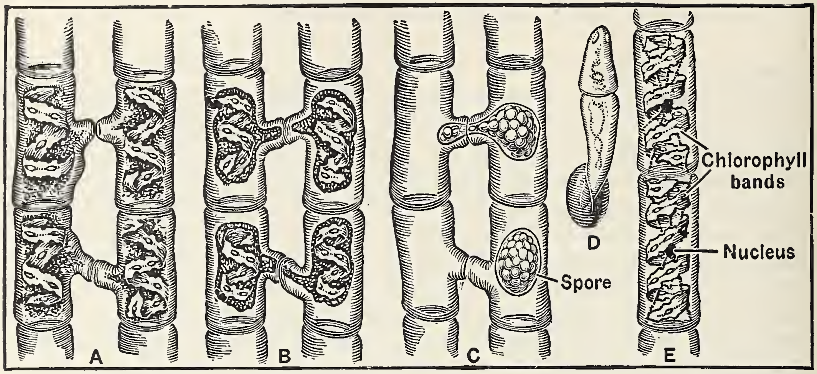
Reproduction with Sex

Questions This Chapter Answers. 1. What is sexual reproduction? · 2. How do sexual and asexual spores differ, and how are they alike? · 3. Does the same plant or animal ever produce more than one kind of sex cells? · 4. How does pollination differ from fertilization? · 5. What are the stages in the development of a seed? · 6. Why is cross-fertilization thought desirable? · 7. What are the stages in the development of the embryo of one of the higher animals? · 8. Are the changes during the incubation of eggs like the development of the mammal embryo? · 9. Why are the numbers of sperms produced by plants and animals so very large as compared with the number of eggs? · 10. Why are few young produced among the higher animals as compared with the numbers produced by the lower animals? · 11. What is meant by alternation of generations? · 12. How is alternation of generations illustrated by the moss and the fern? · 13. How are migration and hibernation related to reproduction? · 14. What are the types and the advantages of parental care?

WHAT ARE THE METHODS OF SEXUAL REPRODUCTION IN THE SIMPLEST PLANTS AND ANIMALS?

Another kind of reproduction. In the types of reproduction which were discussed in the last chapter, only one parent organism is needed to produce offspring. In those types the young organisms may be produced by fission, by asexual-spore formation, by budding, by regeneration, or by some variation of one or more of these methods. Most plants and practically all animals possess means of sexual reproduction, by which a new individual is formed by the union of two cells. The cells which unite are usually from different individuals, though in the case of some plants and animals they may come from the same individual. Many of the plants and animals which reproduce by the union of cells may also reproduce by means of the simpler methods already described.

Simple sexual reproduction: conjugation. During its most active growing season, the strands of *Spirogyra* grow longer through cell division, or fission. Under some conditions, these algae enter into a process of reproduction, called conjugation, that involves two cells. This method of reproduction is sexual. In conjugation the cells of two plants or two cells of the same plant that are near each other produce tube-like growths from their walls. These tubes finally join so as to form one continuous tube between the two paired cells. When the connecting tubes are completed, the protoplasm from one of the paired cells passes through the tube into the other cell. The nuclei of the two cells unite, forming one nucleus. The cytoplasm from both cells then unites into one condensed mass of cytoplasm. This mass surrounds the nucleus and occupies but a small part of the old cell space. The result of this union is a spore.



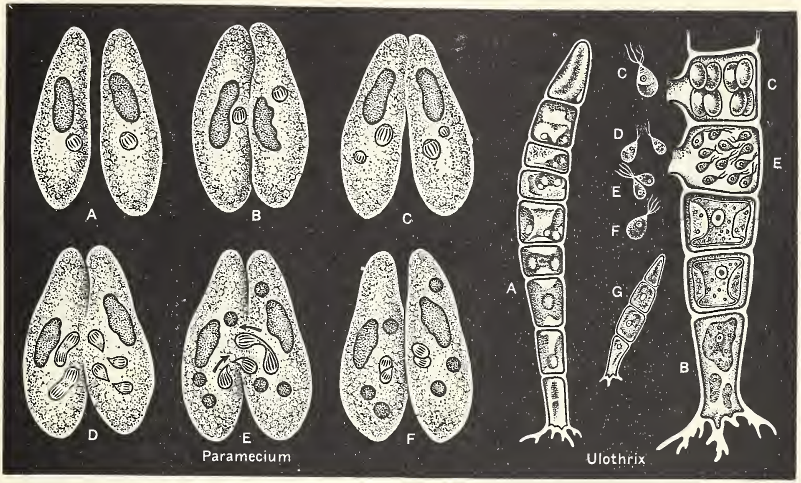
Conjugation of *Spirogyra*. A to C, formation of spore by conjugation; D, a germinating spore; E, two cells of a growing plant. By study of the text can you interpret the stages shown? What methods of reproduction has *Spirogyra*?

As the spore is being formed, it develops a thick wall about itself. The old cell wall surrounding each spore decays and finally breaks, thus releasing the spore. It may sink to the bottom of the pond and remain inactive, or dormant, for a long time. Since it is protected by its thick walls, it may remain alive even though a long period of drought or extremely cold weather may kill all the growing *Spirogyra* plants. When favorable growing conditions return, each spore cell may start to grow as a new *Spirogyra* plant. The cell divides into two cells by fission, and these in turn grow and divide until a many-celled plant has been formed which looks like the parents.

In some of the Protozoa, as *Paramecium*, another kind of conjugation may occur, as is shown in the figure. When two paramecia are conjugating, they exchange portions of their nuclei. Then they separate, and continue to reproduce by fission.

No new paramecia are formed by conjugation. That process seems necessary, however, if fission is to continue. Experiments have shown that after two or three hundred generations have been produced by fission, the paramecia become smaller and smaller and less able to divide. If conjugation is then permitted to occur again, the individual paramecia regain the ability to reproduce normal individuals by fission.

Sex cells. In some of the other algae, it is even easier than in *Spirogyra* to observe that two parents are necessary for reproduction. In some algae (as *Ulothrix*) the protoplasm in one of the cells begins to divide. Finally many small cells are formed within the original cell wall, as is shown in the figure. Then the cell wall breaks and releases them. These small cells have cilia



Judging from these figures, in what respects do you think conjugation of *Paramecium* is different from that of *Ulothrix*, a green alga? **Special Report:** Look up conjugation of *Paramecium* and of *Ulothrix* in advanced zoology and botany textbooks

which enable them to swim about. They are sex cells, or gametes. One of them alone is not able to reproduce a new alga plant, but two of them can unite to form a spore which is able to produce a new alga plant.

Some algae produce two different kinds of gametes. One branch of a plant may produce a single large female gamete, called an egg. Another branch may produce many smaller male gametes, called sperms. The egg usually does not move about. The sperm, however, can swim through the water. Thus it can reach the egg and unite with it. The process of sexual reproduction in which a male gamete, or sperm, unites with a female gamete, or egg, is called *fertilization.*

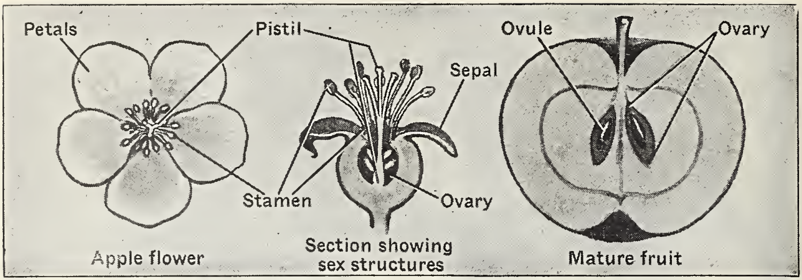
Many animals and plants have definite parts of the body, or organs, which produce gametes. These are called reproductive organs. Usually the sperms, or male gametes, are produced by one individual, and the eggs, or female gametes, are produced by another individual. But sometimes organs for producing both kinds of gametes may be in the same individual.

Self-test. 1. Sexual reproduction is *never* accomplished by one cell.

2. A gamete is *seldom* able to reproduce alone.

3. In conjugation the two gametes which unite are *different.*

4. The *female* gamete seeks the *male* gamete.



Are these complete flowers? Are they perfect flowers? (See the Glossary)

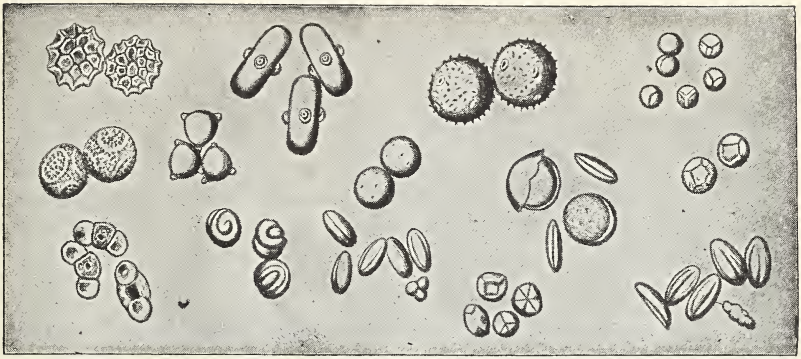
HOW DO FLOWERING PLANTS REPRODUCE?

Flowers. A flower is a special device for reproduction. It consists of many parts, each of which is in some way related to reproduction. No two kinds of plants have flowers exactly alike. Hence any flower used for illustration will be like other flowers in its essential features only. The flower of an apple tree or any other simple flower will provide good material for class use.

Four sets of structures compose the apple flower: (1) the sepals, (2) the petals, (3) the stamens, and (4) the pistil. The outer small and green leaf-like sepals together make up the calyx. In the apple flower the sepals are joined except at their tips. They enclose and protect the other parts of the flower, especially during the bud stage. The brightly colored leaf-like petals together make up the corolla. This structure further encloses and protects the parts of the flower which carry on reproduction. The color of the corolla and the odor of the flower may serve to attract insects which carry pollen from flower to flower. Within the corolla are the stamens. These bear the pollen. At the center of the flower is the pistil. The seeds are formed within the pistil.

Flowers may lack one or more of the four typical structures. For example, the flowers of certain trees, as willow and elm, lack petals. Oaks, mulberries, and squash are among the plants which have some flowers that contain stamens but no pistil, and other flowers that have pistils but no stamens. The stamens and the pistil are the essential parts of a flower, since they are necessary in the production of seeds.

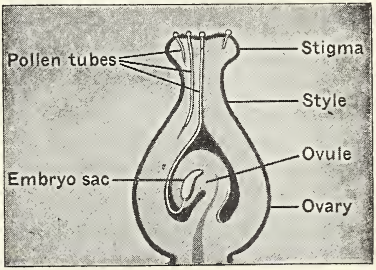
How the seed is formed. The enlarged part near the base of the pistil is called the ovary. The ovary contains the ovules. Inside each ovule is a region called the embryo sac, which will later contain the embryo plant. Within the embryo sac a number of cells are formed. The most important of these are the egg cell, or female gamete, and another large cell which is not a reproductive cell.



Pollen grains. **Project 25:** To study pollen from as many different garden flowers and wild flowers as possible. Make sketches of the types you observe

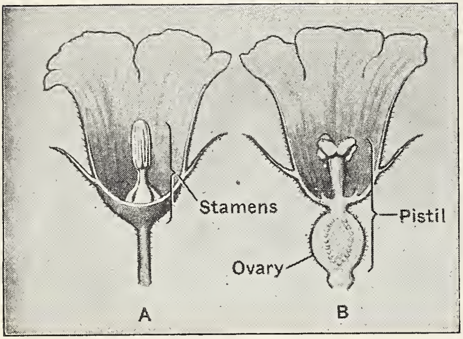
Inside the tip of the stamen the small spores, or pollen grains, are formed. When ripe they escape and are carried by currents of air or by insects, birds, or other animals from flower to flower. If the pollen grains come in contact with the stigma of a mature pistil, they stick to it. Each pollen grain begins to grow. Soon it produces a tube which grows downward through the pistil toward the ovules. Finally two male gametes are formed within this pollen tube.

Upon reaching an ovule the pollen tube grows into the end of the embryo sac and releases the male gametes. One of these unites with the egg and fertilizes it. The other male gamete in most cases unites with the large cell in the central part of the embryo sac. The cell formed by this second union develops into a large amount of nourishing tissue (called the endosperm). This serves as food for the development of the young plant.



Fertilization within an embryo sac. Explain this figure

*The fertilized egg begins its growth at once. The developing new plant is called the embryo. As the embryo develops, it becomes surrounded by the developing food materials (endosperm), which it digests and absorbs. Soon it has formed a small root, one or two leaves, and the beginning of a stem. It then stops growing. The wall of the ovule becomes dry and hard, enclosing the embryo and any remaining food materials. This whole structure is called a seed. Many such seeds may be formed within the ovary of one flower. The young plant remains in a dormant stage during all the time between the ripening of the seed and its later germination.

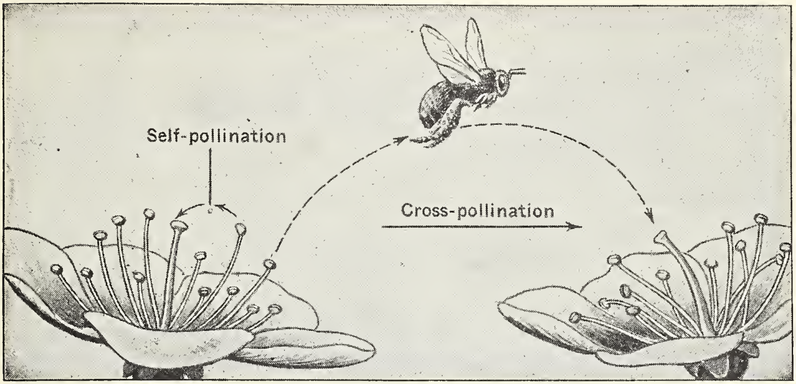


Squash flowers: A, bearing only stamens; B, having only a pistil. Which flower will produce a squash? What part of the flower will produce the squash?

Seeds, fruits, and seed distribution. In many plants, as soon as the seeds are ripe, the ovary opens and releases them. In many others the ovary wall or even other parts of the flower remain around the seeds, forming a fruit. The fruit of any plant consists both of the seeds and of anything else which ripens with them. In the apple and pear, for example, the seeds, the ovary wall, and the sepals develop into the fruit. In the peach and apricot the wall of the ovary divides. Its inner part forms the shell, or hard wall around the seed. The outer part develops into the pulp. The pineapple fruit is formed by the ripening of all the flowers as well as the flower stem and the branch of the plant which produced the flowers.

The fruits serve as aids in securing the distribution of seeds, since birds and other animals eating the fruits carry the seeds away and frequently drop them at some distance from the parent plants. Moreover, the fruits of such plants as the maple and the ash have wings by which they may float short distances through the air. The fruits of such plants as burdock and cocklebur have hooks which may catch in the fur of passing animals. Such adaptations as those of the maple, ash, burdock, and cocklebur result in a wider distribution of these plants.

Stamens and pistils on different flowers. Many of the flowering plants have flowers that bear either stamens or pistil but not both, though both kinds of flowers are sometimes on the same plant. Examples are squash, oak, and corn. Some kinds of plants are said to be either "male" or "female," since their flowers produce but one of the necessary reproductive parts. Examples are willow and holly. Those trees which produce only stamen-bearing (staminate) flowers will, of course, never produce seeds. Only the pistil-bearing (pistillate) trees will produce seeds.



Using this diagram, explain the meaning of self-pollination and cross-pollination

Pollination. In order that flowers may produce seed, pollen must be transferred from the stamen to the pistil. This transfer of pollen is called *pollination*. Pollen may be carried (1) by the wind, (2) by insects, as bees and moths, and (3) occasionally by birds, as humming-birds.

Wheat is commonly self-pollinated. Certain kinds of tobacco have been improved by self-pollination, at least during several generations. Most plants, however, "run out"; that is, they produce fewer and fewer seeds or otherwise show signs of diminished vigor if self-pollination continues.

Self-pollination is somewhat more certain than cross-pollination. The violet and a number of other plants bear two kinds of flowers. These are the familiar large ones, which are cross-pollinated by insects, and small inconspicuous flowers, which are always self-pollinated while they are still closed.

*Plants have many interesting structures that prevent self-pollination and secure cross-pollination: (1) The pollen in some flowering plants ripens and is scattered before the pistil in the same flower is mature enough to permit fertilization of its ovules. (2) The tips of the stamens of some plants open outside, away from the pistil. (3) The stamens of some flowers are too short for the pollen to fall upon the tip of the pistil. (4) Many flowers have colors or odors that attract insects or birds, which in passing from one flower to another may distribute pollen. (5) The structure of the flower may be such as to force an insect to brush against the stamens as it is entering to get the nectar, or to force the insect, as it pushes against the base of a stamen, to bend the pollen-bearing tip over against its back. When the insect visits another flower of the same kind, the pollen which is on it may be brushed off on the pistil of the other flower.

Self-test. 1. Pollen is formed in the *pistils* of flowers.

2. *All* seed plants bear either pollen or ovules or both.

3. The plant embryo remains dormant in the *spore*.

4. *Self-fertilization* occurs in flowers which have only stamens or pistils.

5. With most flowering plants *self-fertilization* serves to make succeeding generations vigorous.

6. Describe the structure of plants that secure cross-pollination.

HOW DO ANIMALS REPRODUCE SEXUALLY?

Sexual reproduction in animals. Sexual reproduction is common. With few or no exceptions besides the Protozoa, all animals reproduce by means of eggs and sperms, though some may also reproduce by asexual means. The sponges, *Hydra* and its relatives, and the worms are among the simple animals that produce both egg cells and sperm cells. These animals usually have both male and female sex organs in the same animal.[1]

Sexual reproduction in the earthworm. Every earthworm is both male and female. In the ninth and tenth segments of the body are organs (called testes; singular, testis) which produce the male gametes, or sperms. In the fourteenth segment are the female sex organs, or ovaries, which produce the female gametes, or eggs.

Two of the animals the sperms of which are mature attach themselves together. An exchange of some of the sperms then takes place between the two animals; that is, each receives some sperms from the other. The swollen region (the clitellum) of each worm secretes material which forms a band, or cocoon. This cocoon is pushed forward slowly by the movements of the worm. As it passes over the openings of the sex organs, the cocoon receives eggs from one of the worms and sperms from the other. The eggs in each cocoon are fertilized by the time the cocoon passes over the head of the animal. The cocoon then contracts. Its surface becomes dry, hard, and brown so that it looks much like a grain of wheat. These cocoons are left buried in rich earth, decaying matter, or under stones and logs, where the adult earthworms live. The fertilized eggs within the cocoon may remain dormant through a period of unfavorable weather.

The embryo earthworms are nourished by secretions left in the cocoon by the parent animal. In two or three weeks twenty or more young earthworms escape from the cocoon and begin to live independently. They soon reach maturity, thus completing the life cycle, and are themselves able to reproduce.

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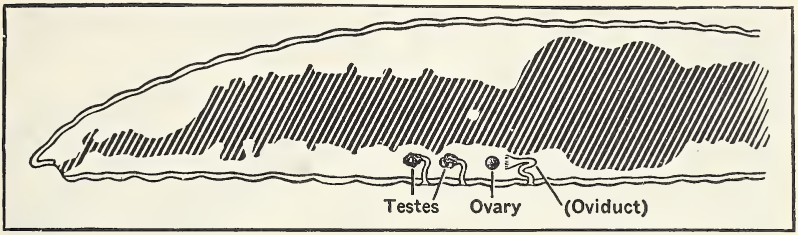
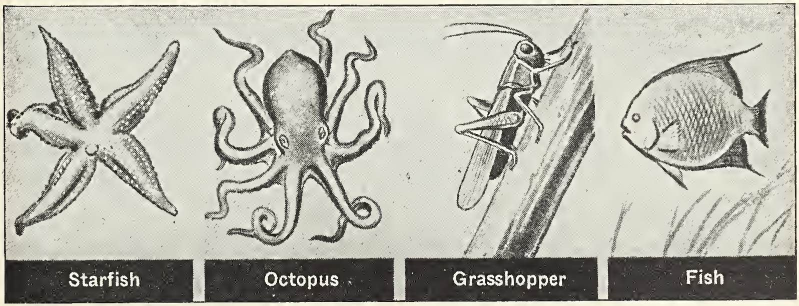
[1] A plant or animal which has both male and female sex organs in the same individual is called a *hermaphrodite* (hûr măf′rō dīt), or a *hermaphroditic* (hûr măf rō dĭt′ĭk) *organism.*



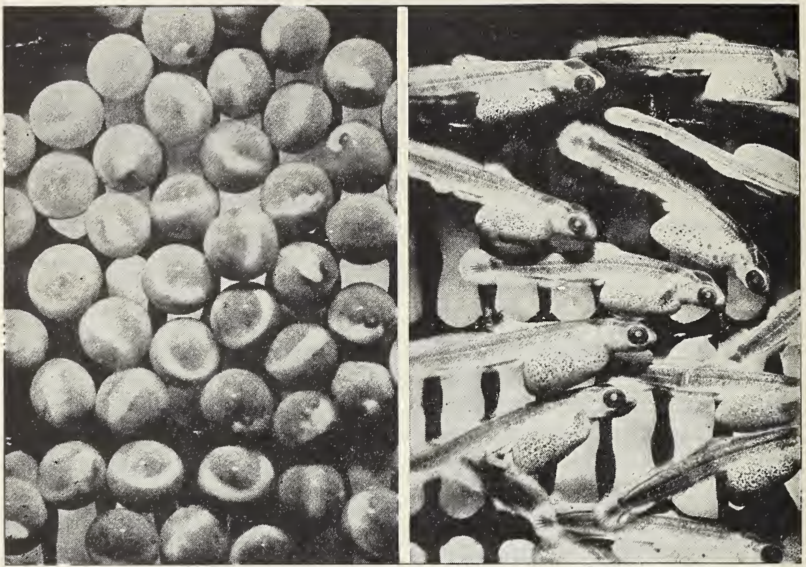
The earthworm has both male and female sex organs. What other hermaphroditic animals can you name?

Reproduction in higher animals. Animals as simple as some of the mollusks have separate sexes. Moreover, all the arthropods and the chordates are either male or female. The lower animals, especially those that live in the water, are very prolific. Thus sponges, jellyfish, oysters, and even animals as high in the scale of life as some of the fishes produce in a single season thousands or even millions of eggs. The males discharge so many sperms as sometimes to make the water around the eggs cloudy. It may perhaps be difficult to understand why such great numbers are necessary when only one sperm is needed to fertilize an egg. A reason is that only a relatively small number of the sperms ever happen to reach the eggs and fertilize them. Moreover, though many embryos begin their development, relatively few live long enough to develop into adults.

In the higher animals, however, fertilization is far less a matter of chance. The males of all mammals, of birds, of reptiles, of some of the fishes, of practically all insects, and of some of the water arthropods, such as the crayfish, deposit the sperms directly in the bodies of the females. Since by this method



Organisms with separate sexes. **Special Report:** Do all other members of the phyla represented here have separate sexes?



General Biological Supply House

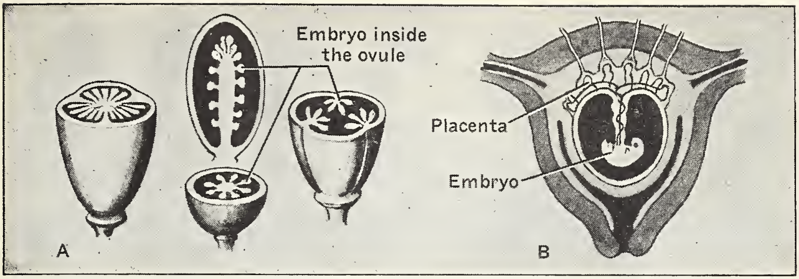
Developing embryos in trout eggs (left); young trout (right). Note that in certain eggs no embryos are developing. How do you account for this fact?

the fertilization of the eggs is practically assured, the numbers of sperms and of eggs of these animals are smaller than those of the simpler animals. In all cases, however, the numbers of sperms are always large when compared with the numbers of eggs. In addition to this provision for ensuring fertilization of the egg, the higher animals also provide more or less care for their young. They therefore produce fewer young than the simpler animals, which leave to chance both the fertilization of their eggs and the fate of their offspring.

Self-test. 1. Animals with both male and female sex organs in the same individual are found as low in the scale of life as the *arthropods* and as high as the *coelenterates.*

2. *Self-fertilization* takes place in the earthworm.

3. The lower plants and animals produce enormous numbers of sperms and eggs because (1) several sperms are necessary in fertilizing each egg; (2) there are so many chances that a sperm will not reach an egg; (3) fertilization is seldom a matter of chance; (4) fertilization of every egg is certain; (5) the organism does not need much of its energy for any other purpose than reproduction.



Plant and animal embryos. What three different arrangements of the embryos and the placentas are shown in these plant ovaries (A)? Compare the development of the mammal (B) with that of the seed. (See "How to Study," p. x)

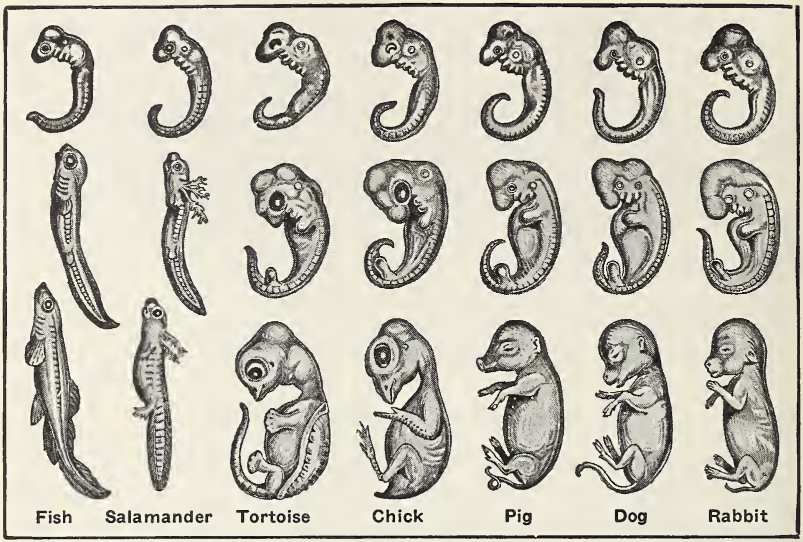
HOW DOES A FERTILIZED EGG GROW?

Development of the embryo. When an egg cell has been fertilized by a sperm, it begins to develop into an embryo plant or animal. By the process of cell division and growth, a many-celled embryo is formed.

The development of an embryo into a complete individual requires constant supplies of food energy. Until it has developed into a mature seed, the ovule of a seed plant remains attached to the walls of the ovary by the placenta, as is shown in the figure, and receives food from the parent plant. Food stored in the seed is used by the young plant from the time the seed germinates until the plant can carry on the work of photosynthesis for itself. The embryo plant has already developed far enough to have its first leaves, stem, and root by the time the seed is ripe. It then goes into a resting stage until conditions become favorable for further development.

What is usually called the egg of a bird or other egg-laying animal is much more than the real egg. The real egg in a hen's "egg" is a small thickened mass attached to the yolk. Most of what is within the membrane and the shell of the "egg" is food which the embryo will use as it develops. The embryo develops but little before the egg is laid. It may then rest for a while before continuing its development.

In the mammals, however, the egg begins to develop as soon as it is fertilized, and it continues to develop steadily with no resting stage. Since the young mammal develops within the mother's body, it does not need stores of energy in the form of food reserves such as are within the seed and the bird's egg. It is attached to the mother's body by the placenta in much the same way that the developing seed is attached to the ovary of the parent plant. Food, oxygen, and other materials pass by osmosis from the mother's



Young embryos look much alike. These figures represent three stages in the development of each of seven animals. Why would the three on the right remain much alike for a longer period of their development than the others would? (After Häckel)

blood to that of the embryo through this tissue. Waste materials pass by osmosis similarly from the blood of the embryo to that of the mother.

The development of the embryo is so nearly the same for all the higher animals that it is difficult to distinguish the embryos of the various animals in the earlier stages of development. The time required for the young animal's development before birth varies with different kinds of animals. The approximate period in dogs, foxes, and wolves is two months; hogs, four months; sheep and goats, five months; cattle, nine months; human beings, nine months; horses, eleven months; and elephants, two years.

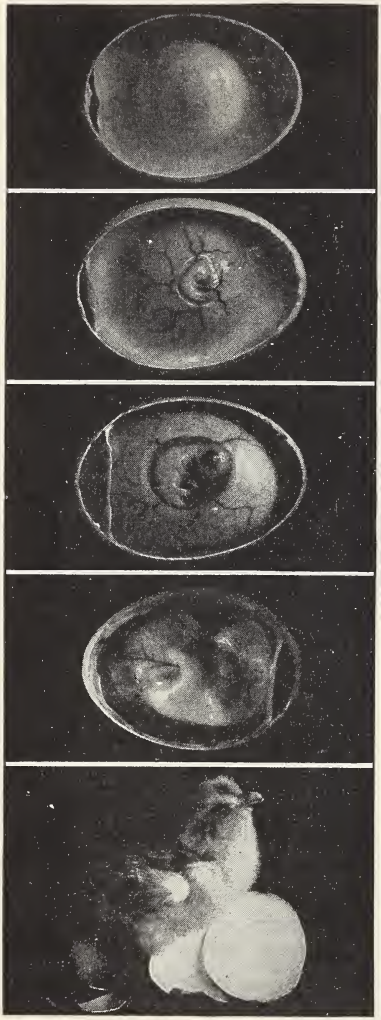
In some animals, as the opossum, the kangaroo, and the bear, the young are born in an undeveloped condition. The mother opossum or the kangaroo has a special pouch in which the young undergo further development. These pouches serve for the protection and transportation of the young. The young secure milk from glands (mammary glands) the nipples of which are inside the pouch. Bears are born during the mother's hibernation. At birth they are but a few inches in length. They remain attached to the mother's milk glands and by the following spring have grown to several times their size at birth.

Newton H. Hartman

Kangaroo and young. What other pouched animals can you name?

Protection of the embryo. The embryo flowering plant begins its life within the protection of the ovule and ovary. Similarly the embryos of all egg-laying animals are protected within the parent's body before the egg is laid. The embryos of such animals undergo still other stages of development while protected by the egg-shell or other covering during the period of incubation.[1] With animals like frogs and most fish, which lay their eggs in the water, the developing embryo is not well protected. The young sponge or coelenterate, however, undergoes the earlier stages of its development within the protection of the parent's body. Likewise the embryos of all those animals which bear their young alive have the protection of the mother's body during the development before birth. Such protection of the embryo plants and animals is of great value in ensuring the survival of the various species.

[1] *Incubation* (ĭn kū bā'shŭn): the process of incubating, or developing an embryo by means of moisture and of heat energy.



A. M. N. H.

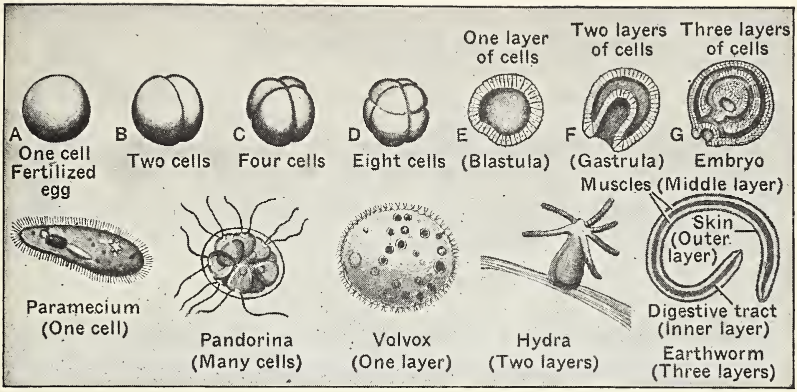
Development of a chick. The pictures show the stages of development on the second, fifth, tenth, fifteenth, and twenty-first days of incubation. What structures can you find in each stage?

Incubation. All fertilized eggs, whether of plants or of animals, require moisture and favorable temperature in order to develop. Hence no flower seeds would germinate into young plants and no animal eggs would grow into young animals without the proper conditions of moisture and of heat. On the other hand, the embryos remain alive within seeds for months, and in certain cases for many years. Then they may develop if conditions of moisture and temperature become favorable to germination. Similarly hens' eggs may be shipped across the entire country without injury to the embryo, provided the egg is not chilled.

There is sufficient heat energy in the water or in the ground where the eggs are deposited to incubate the eggs of the simpler egg-laying animals. The higher egg-laying animals, such as the birds, commonly use the heat energy of their own bodies for the incubation of their eggs. A few snakes incubate their eggs by coiling around them. It has recently been reported, moreover, that the body temperature of the female snake rises during such incubation periods.

The incubation period for birds varies from fourteen days for the smaller species to three weeks for chickens; four weeks for ducks, turkeys, and geese; and forty to forty-two days for ostriches.

With a few fishes, such as the guppy and the ocean perch, and with such reptiles as the garter snake, which also



The development of an embryo, and adult animals that correspond in structure with various stages of the embryo's development. In reaching the adult stage, the more complex animals pass through more stages of development than the simpler ones. Explain how this diagram illustrates this fact

produce their young alive, and with all the mammals, the incubation of the fertilized egg takes place within the body of the female.

Stages of development in embryo animals. Higher plants and animals begin life in the same way, namely, as a fertilized egg. A small active sperm fertilizes a large stationary egg. The sperms of animals are in some cases—for example, one of the sea urchins—only one half-millionth as large as the egg. The sperms of plants and animals all resemble one another more or less, though each kind has distinguishing characteristics.

All animals which develop from a fertilized egg go through the same stages of development. Moreover, these stages occur always in the same order. The fertilized egg, which is a single cell, first divides into two cells, then into four, then into eight, etc. Finally the cell mass resembles a hollow ball the wall of which consists of a single layer of cells (the blastula stage of the embryo, shown in the figure on this page). On one side, cells are thicker than elsewhere. Here the cells begin to fold inward until the developing embryo is a cup-shaped structure (the gastrula stage) somewhat resembling a raspberry. The walls of this cup are composed of two layers of cells. Soon a third layer of cells begins to form between these two, as is shown in the figure. Each layer develops into certain definite structures of the animal's body. From the outer one (ectoderm) develop the skin and the nervous system. From the inner layer (endoderm) develop the linings of all the organs of respiration and of digestion. The third, or middle, layer develops the blood, the blood vessels, the muscles, and the supporting tissues, such as the bones and cartilage, and later the organs of excretion and of reproduction.

Self-test. 1. The embryo in the egg of a *chicken* continues its development from the time it is fertilized.

2. The embryos of the higher mammals are *less well* protected than those of egg-laying animals.

3. The egg of a mammal contains *large* stores of food for the developing embryo.

4. In its development the *embryo* of any of the higher animals goes through stages which *resemble* the adult stages of simpler animals.

HOW IS ALTERNATION OF GENERATIONS RELATED TO REPRODUCTION?

Alternation[1] of generations. *In several of the lower animals, and in all but the lowest plants, the life cycle consists of two distinct phases, or parts. Together these make the complete life cycle. One of the phases produces eggs and sperms and therefore reproduces sexually. The other phase produces asexual spores and therefore reproduces asexually. For example, the free-swimming stage of the jellyfish reproduces sexually. The eggs develop into hydra-like animals that attach themselves to a support. This non-swimming stage later divides to produce free-swimming jellyfish. Thus the free-swimming sexual generation and the non-swimming asexual generation continue to alternate.[2] Moss and fern plants provide good illustrations of alternation of generations in plants.

The life cycle of the moss. The various phases of the life history of the moss are shown in the figure on this page. Let us begin with the sexual phase. In this phase the plant which later develops sex cells, or gametes, begins its growth from an asexual spore. The young plant is at first branched and thread-like. Buds form on the branches and produce root-like structures (rhizoids) which extend down into the soil. The buds develop into the leafy plants, that is, plants having many leaves. These plants are what most people recognize as moss. During the part of the life history thus far described, the moss plant makes its own food by photosynthesis.

Sex organs later develop on the ends of these leafy plants. Many sperms develop in each male sex organ (antheridium), and one egg forms in each female sex organ (archegonium). By means of cilia the active sperms swim in any moisture which may be on the leaves. When by chance one of them reaches an egg, it fertilizes the egg.

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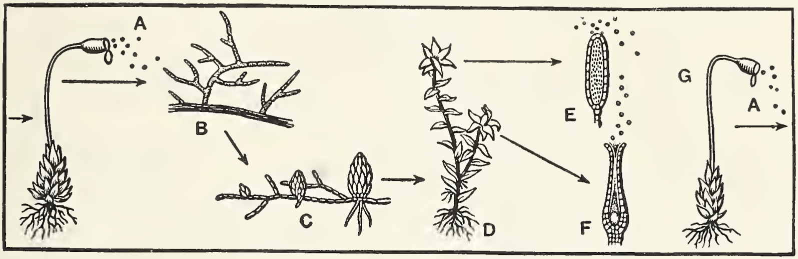
[1] *Alternate* (ôl'tẽr nāt): to continue to "take turns," first one and then the other, over and over. *Alternation* (ôl tẽr nā'shŭn): act of alternating.

[2] See alternation of generations in the jellyfish, pp. 160–161.



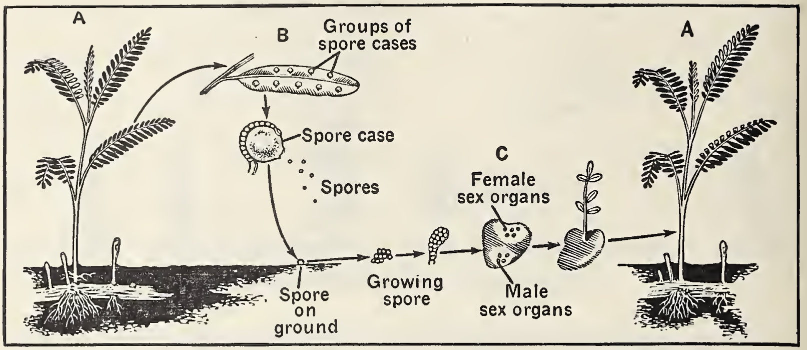
Life cycle of a moss. Explain this diagram

The other generation of the plant now begins to develop from the fertilized egg. This other phase of the life history is the asexual phase. The fertilized egg starts growing at once, forming an embryo. The embryo develops a stem without leaves, an inch or more long, upon the tip of the old leafy plant. A spore case later forms on the end of this stem. The stem and the spore case both contain some chlorophyll and therefore carry on photosynthesis. Most of their nourishment, however, is secured from the old leafy plant. Spores develop in the spore case. Since these spores are formed entirely by division of cells, and not by the union of cells, they are asexual spores.

When mature, the spore case opens, releasing the spores. These are exceedingly small and light, and therefore may be carried long distances by the wind. If they fall in favorable places, they grow. The moss plant which develops from them is the sexual phase, with which this discussion began.

The gamete phase of the moss plant (gametophyte) never produces the gamete phase, and the asexual-spore phase (sporophyte) never produces the asexual-spore phase, but each phase produces the other. Each stage is sometimes called a generation, but it is merely a part of a life cycle and not a generation such as a human generation.

Experiment 61. How do fern spores develop into fern plants? Secure an earthen brick which will readily absorb water. Immerse it in water and, while its surface is still wet, hold it close to a fern plant the leaves of which have ripe spore cases. Shake the leaf; then stand the brick with one end in a dish which contains two or three inches of water. Keep the dish and brick in a warm place which is neither in direct sunlight nor in darkness. After a few days watch for young fern plants and learn what you can about how they grow. Why is the brick to be kept standing in water? Why is it placed in a medium-lighted warm place? How many days is it before the first green growth can be found? How many days until a fern leaf can be found?



Life cycle of fern. Explain this diagram

The life cycle of a fern. The various phases of the life history of the fern are shown in the figure on this page. Let us begin with the asexual (spore-producing, or sporophyte) phase. In this phase the plant has the familiar form in which most people recognize the fern. On the under-sides of the older leaves of most of the common ferns, there are brown scale-like patches which develop as the growing season advances. These are made up of spore cases (sporangia) and the leaf membranes that cover them. Asexual spores are formed in the spore cases. A single large fern plant sometimes produces several thousand spore cases and hundreds of thousands of spores during a single growing season.

When ripe, the spore case opens in such a way as to throw the spores with considerable force. This action of the spore cases and the currents of air which carry the spores give them wide distribution.

The fern spore begins to grow and soon produces a flat green heart-shaped body. This is the gamete-producing (gametophyte) phase of the life cycle. These small plants sometimes grow in such abundance that they completely cover the moist ground or the surfaces of pots in greenhouses. When they grow on the soil out of doors, they are not readily seen, and therefore few people ever notice them. The young plant has chlorophyll and hence can manufacture food. Therefore this stage of the fern can live independently.

The two kinds of sex organs are produced on the under-sides of these heart-shaped fern bodies. In some species of ferns, the male and female sex organs grow on the same plant. In other species, they grow on separate plants. The female sex structure, which contains the egg, is partly buried in the plant. The active sperms from the male sex organs swim to the stationary egg, and one fertilizes it.

Indians spearing salmon. The salmon are returning from the ocean to fresh water to spawn. Are the reactions of the Indians and the salmon learned or unlearned? Explain

The fertilized egg does not have a resting period, but starts its growth at once by cell division. It now begins to develop the asexual (sporophyte) phase of its life cycle. One part of the developing egg, or embryo, spreads out as a foot, or attaching structure. The embryo fern plant absorbs its nourishment, through this foot, from the tissues around it. It soon develops a root, stem, and leaf. Even when small, the leaf may be recognized as like the one upon which the asexual spores developed.

From this discussion and the discussion of the moss, we see that in alternation of generations each generation produces reproductive cells, which when they grow form the other generation.

Self-test. 1. In alternation of generations each stage resembles its *parent*, but not its *grandparent*.

2. The stage of the fern which produces the male and female sex structures is *wholly* self-supporting.

3. The brown patches on fern leaves are composed of *sex organs*.

4. The gamete stage of the fern or the moss produces the *gamete-bearing* generation.

WHAT ANIMAL BEHAVIORS ARE RELATED TO REPRODUCTION?

Behaviors preceding mating. Many of the higher animals have peculiar and often complex instinctive behaviors closely related to reproduction. Some male birds and male mammals have mating calls which they make only during the mating season. The "drumming" of male ruffed grouse and of pheasants is a mating call. Male birds, such as the turkey, the peacock, and many smaller birds, spread their plumes and strut before the females of their kind. Male deer, elk, and moose are timid during the spring and summer, when their horns are growing and becoming strong. But they become savage and dangerous during the autumn mating season, when their horns have become fully developed. Fighting between males during the mating season is common among Chinese pheasants, foxes, horses, elephants, rhinoceroses, and many other kinds of higher animals. The vanquished male is either killed or driven away by the victor. The result is that only the fiercest and strongest males are likely to become the fathers of young wild animals.

Migration. The migration of some animals, especially certain fish and perhaps the birds, is related to reproduction. Let us consider, for example, the migration of the salmon of Alaska and the Pacific Northwest. The female salmon lay their eggs in the shallow headwaters of the high mountain streams. The males then fertilize the eggs. Soon after fertilization has been accomplished, the old fish usually die or are caught by animals that feed upon them. The eggs develop into a new generation of salmon.

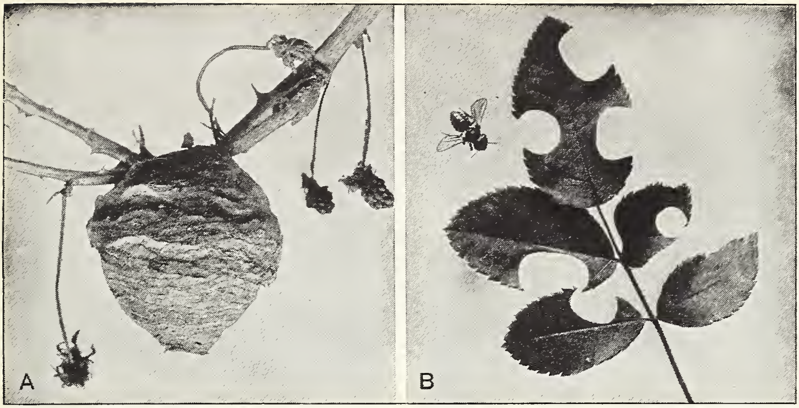
When but a few weeks old and while still small, the young salmon start downstream. After they reach the ocean, they are thought to follow fairly definite "trails," sometimes going more than a thousand miles from the mouths of the streams from which they came. They live in the ocean probably three or four years, until they are mature. Then, as their sex cells start developing, they begin the return journey to regions like those in which they began their life. They find their way to the mouths of fresh-water streams, which they enter. They then swim upstream in large numbers, making great haste and crowding one another. Sometimes the males fight viciously, tearing great wounds in one another's bodies as they hurry onward. When the salmon come to waterfalls, they jump against the current. If the falls are not more than a few feet high, the stronger ones succeed in getting over them and continue their journey to their breeding regions. As they proceed, their bodies, which were fat when they started, become thin. They deposit and fertilize the eggs; then they die or soon become easy prey to enemies. Thus the life cycle is completed.

The common eel reverses the story of the salmon. It lives part of its adult life in fresh water but returns to the ocean to reproduce. Later the young slowly find their way back to the kinds of fresh waters from which the parents came.

At the spawning time some fish, such as smelts, travel in great schools. These so crowd the mouths of small streams that people are sometimes able to dip them up in great quantities, using dip nets, pails, or even gunny sacks tied over barrel hoops.

As has been stated, some scientists have proposed the theory that there is a relation between the migrations of the birds and the development of their sex cells. They suggest that the birds begin their migrations when their sex cells have reached a certain stage of development. Some support of this hypothesis is found in the fact that the spring migration is definitely associated with the return of the birds to their nesting places.

Hibernation in relation to reproduction of frogs and toads. Hibernation of frogs and toads has an important relation to their reproduction. During the summer and autumn they devour and store large quantities of food. At this time their sex organs are undeveloped. During hibernation the sex cells develop. When the earliest warm weather of spring comes, the frogs dig their way to the surface and at once begin to hunt for pools or ponds as places for reproduction. Although their reserve energy is now almost exhausted, the frogs do not hunt for food until their eggs have been laid and fertilized. Experiments in trying to get frogs to feed at this time have been unsuccessful.



Cornelia Clarke

A, nest of paper wasp; B, leaves from which sections have been cut by the leaf-cutter bee.
Special Report: How do these insects make their nests?

Self-test. 1. Many of the *lower* animals which are ordinarily timid may become fierce during the mating season.

2. The *stronger* fish are more likely to reach the spawning grounds than the *weaker* ones.

3. The eel spawns in *fresh water.*

4. Salmon spawn in *fresh water.*

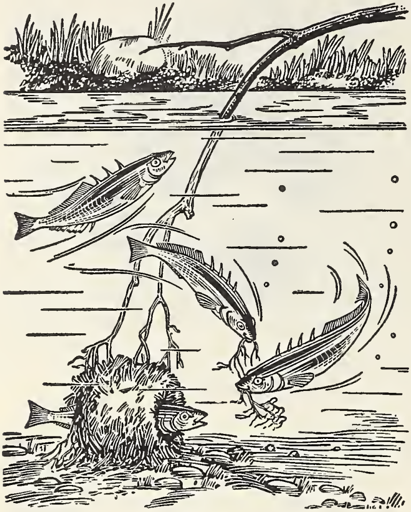
5. Amphibia, such as frogs and toads, hibernate during the *spring, after* their gametes have become fully developed.

WHAT ARE SOME BEHAVIORS RELATED TO CARE OF OFFSPRING?

Nest-building. When we hear the word *nest,* we are likely to think only of the home of a bird because that is the most familiar kind of nest. But if by *nest* is meant any sort of artificial shelter which an animal builds as a place in which to take care of its young, then there are many animals which make nests. However, animals relatively high in the scale of life are the only ones that build nests, since only these take any care of their young.

Many insects, such as ants, honeybees, and hornets, make elaborate nests. Bees make special wax cells to accommodate the eggs. Some spiders spin egg cases, in which the young spiders live for a time after hatching from the egg.

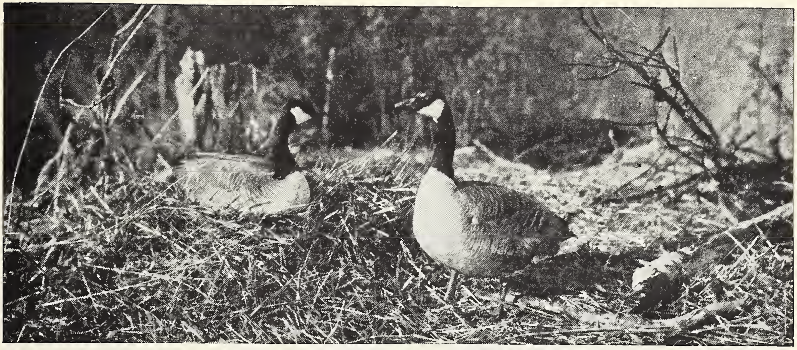
Most kinds of fish pay no attention whatever to their young, other than perhaps to pursue and capture them for food. A few species, however, make nests and care for their offspring for a short time much as the birds do. When the mating season arrives, the male stickleback, a small fish common in inland streams and lakes, builds a nest of sticks on the bottom of the stream or pond. He fastens the sticks together with threads secreted from special glands. When his nest is completed, he remains outside to entice the females to lay eggs in the nest. Each female can lay from fifty to a hundred rather large eggs, but she lays only a few in one nest, perhaps only one. As soon as she departs, the male fertilizes the eggs she has left and then continues to entice other females. Often several females will lay eggs in the same nest.



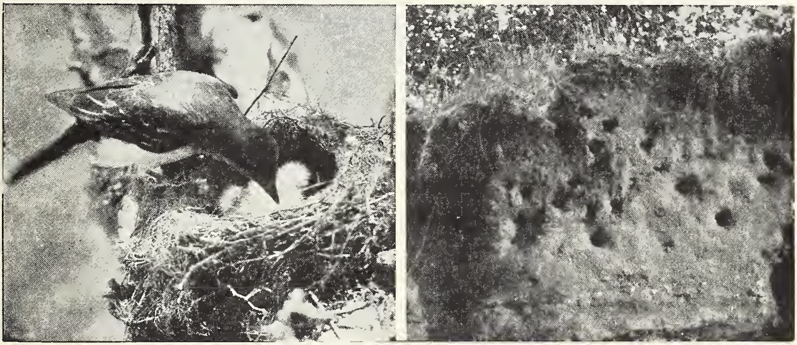
Sticklebacks and their nests. **Self-test on Biological Principles:** Using the facts presented in this picture and in the text, can you explain this principle: "The greater the degree of parental care, the less is the need for a large number of eggs or of offspring"?

The male bowfin, or fresh-water dogfish, a fish about eighteen inches long that lives in the quiet waters of the Mississippi Valley and Great Lakes region, makes a nest on the stream bottom by clearing a space with his fins and tail. Bass and sunfish likewise build nests by sweeping a circular depression in the sand or fine gravel. Some kinds of fish use their noses and heads to roll stones about until they have made an irregular pan-like area with smaller pebbles in the bottom and around its boundary.

Birds build nests of many shapes and sizes and in many locations. Most ground birds build rather crude nests on or near the ground. The young of these birds are able to run about and secure their own food almost as soon as they are hatched (precocial birds). Ducks, chickens, and pheasants make such nests. The young of certain other birds are hatched in a helpless condition. They are almost naked and blind and are unable to feed themselves. These birds build more substantial nests in which the young can be reared. Such birds (altricial birds) include the robin, red-winged blackbird, oriole, catbird, and the sparrows. The cowbird is a widely distributed native bird which lacks the nest-building instinct. It lays its eggs in the nests of other birds, which incubate and feed the cowbird young.



Hutchins's geese



Lynwood M. Chace

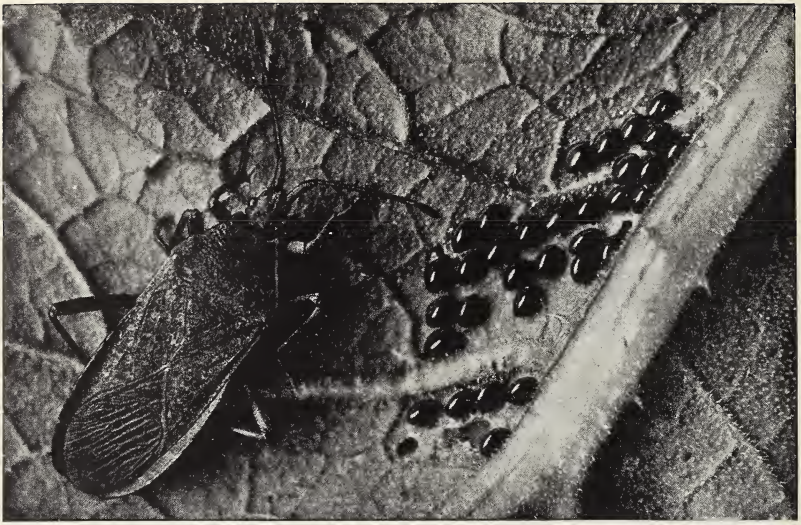
Kingbird

Tunnels made by claybank swallows for their nests

Nesting habits of birds. **Self-test on Biological Principles:** Should you infer that the young of these geese would, when first hatched, be more helpless or less helpless than the young of the kingbird and the swallow? Make a statement of a biological principle which summarizes these facts

Sometimes the male bird builds the nest, but more commonly this work is done by the female. When both birds of a pair work at the nest, most of the work is usually done by the female. In the case of the singing birds it is not uncommon for the male to sing in the vicinity of the nest or to fight intruding birds, while his more industrious but less musical mate constructs the home for their future offspring.

Few of the reptiles make any sort of nest. Turtles bury their eggs in the sand and allow the earth's heat to incubate the eggs. Alligators sometimes



Cornelia Clarke

Squash bug and eggs. Does this picture illustrate parental care? Explain

bury their eggs in high mounds which they build of plants and decaying vegetation. This material ferments, thus producing the heat energy needed in order to incubate the eggs.

Mammals, such as beavers and muskrats, field mice, gophers, and squirrels, build houses or dens of one sort or another in which to live and rear their young.

Parental care. No behavior which could correctly be termed parental, or parents', care has been observed of animals lower in the scale of life than the arthropods. Only a few insects care for their young. They seem, however, to possess the instinct to lay their eggs where there will be suitable food ready for the young as soon as they hatch. The potato beetle usually places its eggs on the under-sides of the leaves of plants of the potato family. The monarch butterfly usually chooses the milkweed plant. Insects such as the mosquito, the young of which are fitted only for aquatic life, lay their eggs in or near the water.

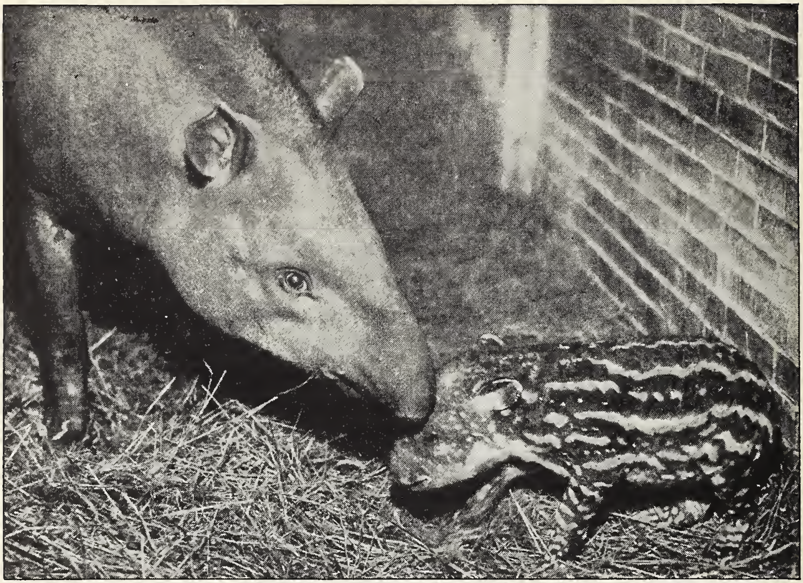
Some of the higher insects, such as the honeybee and the ant, give elaborate care to the young, providing them with special food and remarkable attention. The female spiders of some species guard their egg cases until the young emerge; then they carry the little spiders about on their backs until the young ones are mature enough to survive without help.

Most of the nest-building fish give some care to their young. The male stickleback and the male bowfin guard their nests, for eight or ten days, until the young are hatched and for a few days afterward. The male bowfin then accompanies them, much like a mother hen with her brood of chicks, and protects them until they have grown to be three or four inches long. There are rare kinds of fish that not only carry the eggs in the mouth and pharynx until the eggs hatch but also continue to carry the young fish until the latter are able to shift for themselves.

Birds furnish parental care of several kinds in addition to incubation. The young of most birds are dependent upon their parents for food. Most of the smaller birds feed their young on various soft-bodied insects or insects in the larval stage. The larger birds, such as eagles and hawks, feed their young upon small mammals and other birds which they capture. The large and hungry mouths of young birds seem to be always ready for more food. One robin was observed to bring four worms at one time. She gave one worm to each of her four young birds, which promptly stretched up their necks and opened their mouths begging for more food. A few kinds of birds, such as pigeons and doves, feed their young by the use of food which the parents have swallowed and partly digested, or by the use of a secretion (called crop milk) which is produced within the parent's digestive system. Until the young birds leave the nest, and in many species for a considerably longer time, the parent birds protect their young, to keep them warm and to shelter them from rain. It is an amusing sight to see a mother hen attempting to cover her lusty youngsters after they have become so large that she sits unsteadily upon their heads and backs, scarcely able to get a toe on the ground.

Birds, as well as the mammals, will often fight bravely for their young. You have perhaps observed parent robins chasing a squirrel from their nest, which he had begun to rob, and driving him to greater haste with frequent vicious pecks. Robins have been known even to attack people near their nests. A mother hen was observed to kill a harmless garter snake which had the misfortune to glide near her brood of chicks. She rained blows with her beak upon the snake's head and gave sharp cries of warning to her chicks. These stood about her in a circle, their necks stretched forward while they uttered subdued chirps of alarm.

The male mammals of some species share with the females the work of caring for the offspring. This is not true of all mammals, however. The male cat, for example, would eat his offspring were it not that the mother cat, which becomes especially fierce when her kittens are young, fights him away. The male horse, or stallion, however, fights valiantly to protect his herd and has been known to vanquish a bear which was trying to capture a colt.



Newton H. Hartman

A mother tapir and her two-day-old baby at the Philadelphia zoo. How does this picture illustrate reproduction, growth, and change?

Length of period of parental care. Different kinds of birds require different lengths of time to grow to their mature size. Young robins may grow so rapidly that they may be ready to fly from the nest in ten days, though usually about two weeks are necessary. Chickens, turkeys, and geese require six to eight months, and the ostrich may require two years or more to reach full maturity.

Many young mammals, such as kittens, pups, and baby mice, are born blind, and all mammals are more or less helpless at birth. Their digestive organs, muscles, bones, sense structures, and nervous systems are far from being mature. Even if they could secure meat or plants, they could not then use them as food. The young mammal, unlike the young frog or turtle, could not survive without the care of its mother. She furnishes it with milk for food and with shelter, warmth, and protection. The period during which parental care is needed varies with different mammals from a few weeks to several years.

A longer period of parental care increases the chances for the survival of each individual, and consequently a smaller number of young will maintain the species.

Self-test. 1. The simplest animals *rarely* build nests.

2. *No* fish build nests.

3. Reptiles which build crude nests are --?-- and *alligators.*

4. Few of the *mollusks* have been observed to care for their young.

5. The lowest chordates which have been observed to care for their young are some of the *reptiles.*

6. Some *male* mammals will fight for their young, while other *male* mammals will devour their offspring.

Self-test on Important Biological Terms

alternation of generations
calyx
conjugation
corolla
cross-pollination
embryo
fertilization
flower
gamete
hibernation
life history
migration
petal
pistil
pollen
pollen tube
pollination
self-pollination
sepal
stamen

Self-test on Biological Principles. 1. Can you state evidence from this chapter to explain this principle: "Nature is wasteful of life"?

2. If several pollen grains fall upon a mature pistil at the same time, all may begin to grow tubes toward the ovules, but the strongest will reach the ovules first. Similarly a million sperms may begin at the same time to swim toward the egg in one of the higher animals. One of the most vigorous will reach and fertilize the egg. How do these facts illustrate "survival of the fittest"? What advantage does the plant or animal gain from such "waste" of life?

3. How many illustrations of this principle can you give: "The number of young produced by an organism is in inverse proportion to the amount of parental care given to the young"?

4. What evidences can you find in the story of the migration of salmon which tend to prove "the survival of the fittest"?

5. Can you explain why in each of the following paired statements *a* is incorrect and *b* correct in accordance with this principle: "Those plants and animals are most likely to survive and reproduce which have structures and adaptations best fitted to the environment"?

a. Some plant seeds have hooks *in order that* these may catch in the fur of passing animals, thus carrying the seeds to new localities.

b. Some plant seeds may be carried to new localities *because* they have hooks which may catch in the fur of passing animals.

a. Certain animals have protective coloration *so that* they can more successfully escape their enemies or catch their prey.

b. Certain animals may more successfully escape their enemies or catch their prey *because* they have protective coloration.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. What do you think are some of the advantages to *Spirogyra* gained from its kind of spore formation?

2. Explain why, according to the definition given in this chapter, the following may be called fruits: tomato, cucumber, pea pod, and cocklebur.

3. What conditions can you name which might prevent the fertilization of fish eggs by sperms discharged into the water near the eggs?

4. What examples of cross-pollination, other than those discussed in this chapter, can you find by examining flowers or by reading in botany textbooks?

5. Why does a female stickleback or a female dogfish not need to lay so many eggs as a cod or an eel?

6. Why is it of more advantage to amphibians, such as frogs and toads, and to insects, such as butterflies, to lay their eggs in the spring rather than in the winter?

7. Compare the incubation of birds' eggs with that of frogs' or toads' eggs (see "How to Study," p. x).

Exercises on Scientific Method. 1. *Weighing Facts.* The young of several of the mollusks, such as the clam and the fresh-water mussel, undergo part of their metamorphosis while protected within the shell of the female. Is this protection true parental care? Justify your answer.

2. *Making Hypotheses.* Plants brought into a new region often grow very well but do not produce fruit. What possible explanations can you offer?

Special Reports. 1. Alternation of generations takes place in all flowering plants, but the sexual generation is not easily observed. The entire development of the sexual generation takes place within the structures of the flower. Study this topic in an advanced botany or biology text and prepare a class discussion of it.

2. Not all Amphibia lay their eggs in water, as do the common frogs, toads, and salamanders. How do the Surinam toad, the lungless salamander, and the obstetrical frog take care of their eggs? Perhaps an encyclopedia will provide the needed information.

3. How is a queen bee made to develop from a worker larva? What are the ant "nursemaids"? You can find discussions of these topics in an advanced zoology or entomology text or in an encyclopedia.

CHAPTER XXIX

Factors of Inheritance

Questions This Chapter Answers. 1. To what extent and in what ways may offspring of the same parents differ? · 2. What are the structures that control inheritance? · 3. What are Mendel's laws of inheritance? · 4. Are acquired characters ever inherited? · 5. How has man applied the laws of inheritance in improving plants and animals? · 6. Do the Mendelian laws apply to human inheritance?

HOW DO PLANTS AND ANIMALS CHANGE?

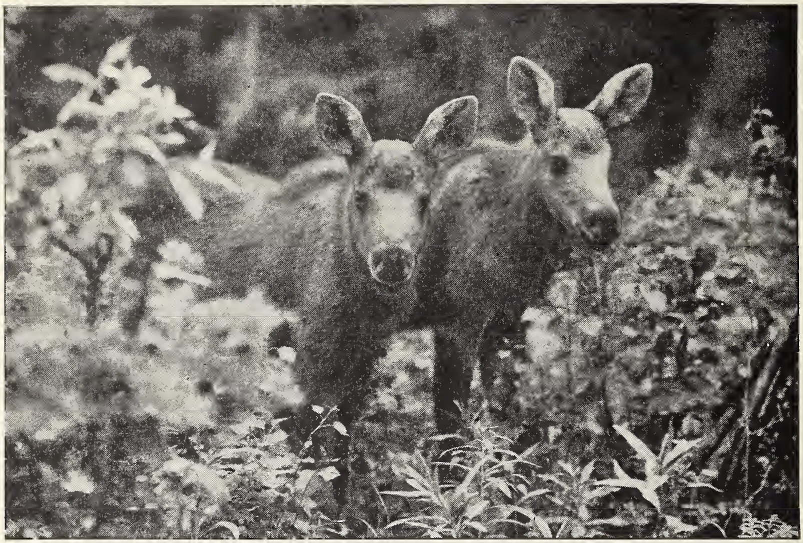
Individual variations.[1] It is not unusual to find twin boys or girls who look so much alike that only those who know them best can tell them apart. Usually, however, twins have distinguishing characters[2] that will be noted by careful observation. Slight differences, such as those in structure, in voice, in ways of walking, or in eye movements, may be noted.

Probably no two individuals are ever exactly alike. When the large number of characters which might vary are considered, it seems strange that plants and animals of the same kind are as much alike as they are. Yet there are more ways in which individuals of the same kind resemble one another than ways in which they differ. When, however, unknown plants and animals are being studied, the individual variations that are found are sometimes great enough to make it difficult to determine correctly the species to which a particular animal or plant belongs.

Extent and nature of variations. Variations among living things may appear in one or in many characters. Thus some of the dogs that are of the same litter may have pointed ears and some may have blunt ears. Some may have short legs and some long legs. Some may have long noses and some short noses. Some may be black and some white. Some may grow rapidly and others slowly. If all those that have blunt ears should also have short legs, short noses, be black, and grow rapidly, while all the others should have the opposite characters, then the dogs of the same litter would appear almost like two distinct kinds. But the variations may be distributed in other ways. That is, one large white dog may have a short nose, pointed ears, and short legs, and may grow rapidly. Another large white dog may have a long nose, pointed ears, and short legs, and may grow rapidly. Other combinations of these five qualities, characters, or factors may occur. Then there are many other factors besides color, rate or extent of growth, length of nose or of legs, and shape of ears which may vary with each dog.

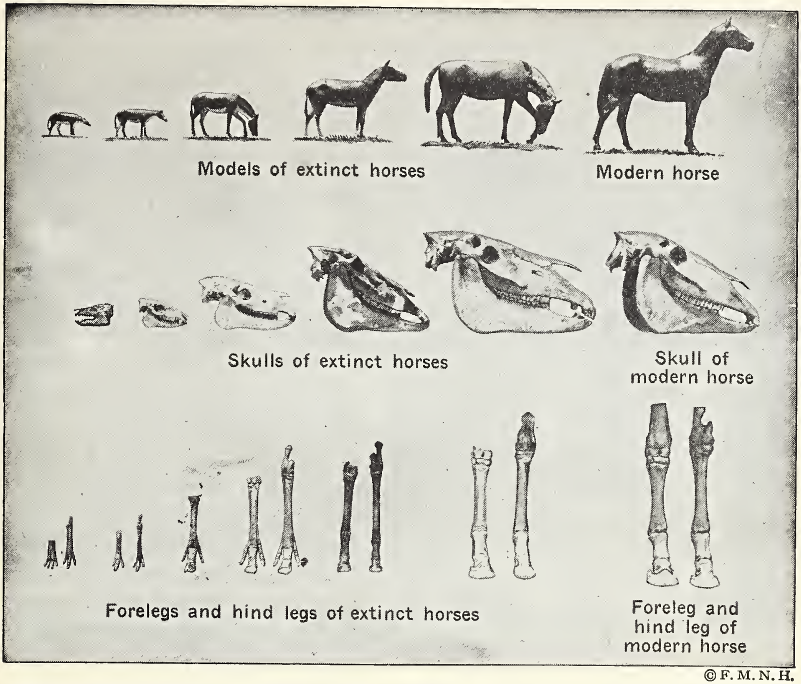
[1] *Variation* (vâr ĭ ā'shŭn): difference in structure or function from the parent.

[2] *Character* (kăr'ăk tẽr): any characteristic, such as size, color, length of limb, and so on.



Twin moose calves in Riding Mountain National Park, Manitoba. Name several ways in which these similar animals would be likely to vary

Slow changes through slight variations. While ordinarily variations among individuals of the same kind are slight, nevertheless a slight variation may mean survival or death to the plant or animal possessing it. For example, if it occurs that the only animals that can reach their food are those that vary so as to be taller, the shorter ones will be less likely to survive in the struggle for food. The taller ones therefore will be more likely than the short ones to reproduce. Again, in the succeeding generations there will probably be an increasing proportion of tall individuals because most of the short ones of each generation will starve to death before they become mature enough to reproduce. Under such conditions there might develop through many succeeding generations only tall animals of this kind. Thus what appeared as a variation might finally become established as a fairly constant character of this kind of animal. At the end of a long period of time the animals might be very different from their remote ancestors. Yet those of any given generation would seem but little different from those of either the preceding or the following generation. Scientists believe that it is through variation and selection over a long period of time that many new species of plants and animals have developed.



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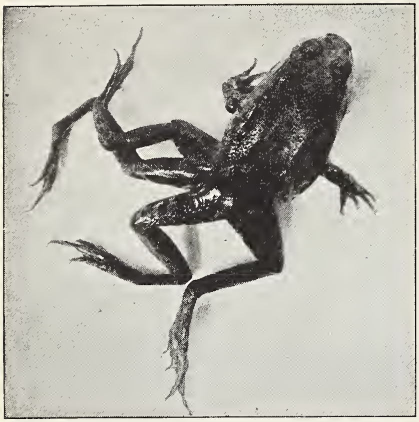
The slow development of the horse. Trace the changes in the structure of the foot from the primitive horse to the modern horse. Should you infer that the habitat of the modern horse is the same as that of the primitive horse? Explain

Fossils have been found which show that many of our common animals have changed slowly through the ages. The figure on this page shows this fact in relation to the horse. The first horses are believed to have been five-toed animals no larger than dogs. They lived in the swampy forests. Fossil bones show that in later periods the horse had three toes on the hind feet and four toes on the front feet. This horse was somewhat larger than its early ancestors. It lived on the grassy plains of central North America. As the ages passed, the hind toes became shorter and finally disappeared. The modern horse stands on the toenail of the middle toe. The only remaining evidences of the other toes are shown by bones in the leg of the horse.

Mutants and mutation. *Variations in living things of the same kind are not always slight. Once in a while an offspring is produced which looks very different from any others of its kind. It possesses one or more characters which vary considerably from the normal. If the new character is "passed on" to the following generation, that is, if offspring of the changed plant or animal inherit the character, then that character is called a *mutation.* The individual in which the mutation first appeared is called a *mutant.* For example, hornless cattle did not develop by a gradual shortening of the horns and a final disappearance of them through succeeding generations. This character appeared suddenly. In more than one instance a calf was born without the "horn buttons" which develop into horns, although its parents and all its ancestors, so far as was known, had horns. The different types of hornless cattle which we now have became established through mutations such as these.



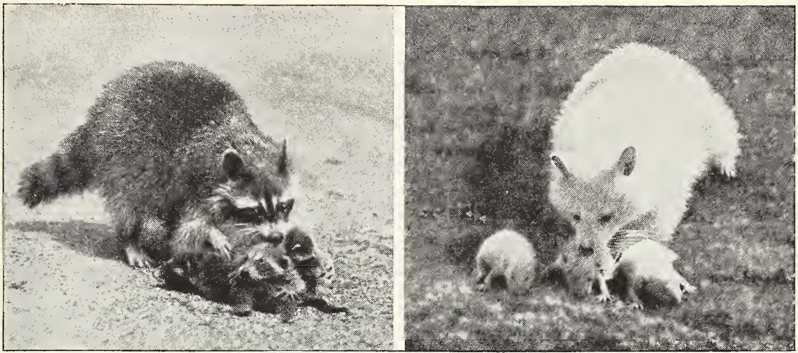
A six-legged frog. An animal or a plant which varies considerably from others of its kind, but which does not transmit the difference to its offspring, is called a freak. How could one determine whether this frog is a freak or a mutant?

A mutation may consist either of the loss of some character which is normally possessed by a species of animal or plant or of an additional character. An example of a lost character is color in such mutants as white crows, white blackbirds, white rats, and the like. An example of an added character is the extra finger which is found on the hands of some people.

Like the small variations, mutations may give the organisms possessing them a better or a poorer chance to survive than the normal individuals have. For example, if the mutation is a conspicuous color, the individual may more easily become prey to enemies, or it may have more difficulty in capturing prey. But if the mutation is a better protective coloration, the individual may more easily escape the enemies of its kind and may more easily capture prey.

The difference between ordinary variations and mutations seems to be chiefly one of the extent to which the offspring varies from its parent. A mutation is a sudden appearance of a character strikingly different from the normal. It is not the result of many slight variations which have occurred from generation to generation. A suggested explanation of these facts is given later.

Producing new kinds by crossing. When pumpkins and summer squashes are grown near each other, the pollen from one may be deposited within the



Lynwood M. Chace

Ben East

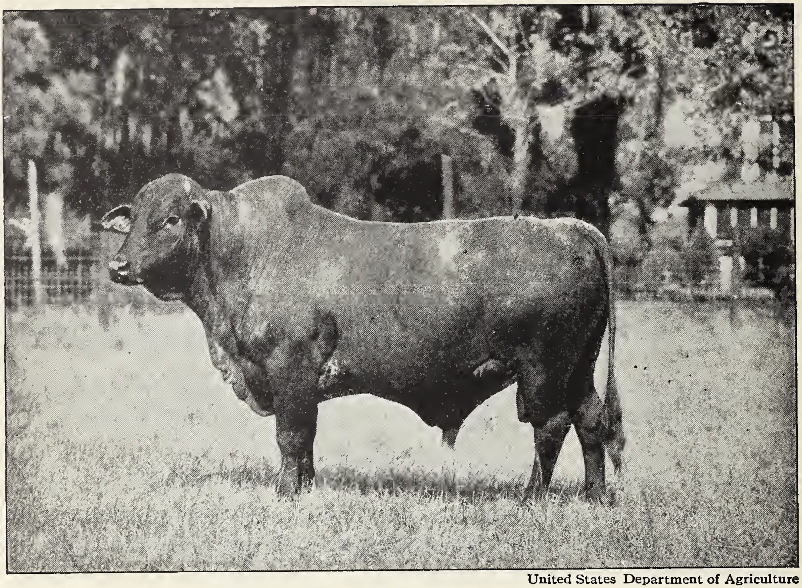
These mother raccoons are gently carrying their helpless babies back to the nest. How does this picture prove that the white mother raccoon is a true mutant?

flowers of the other. It is likely that pollen from other neighboring plants, as ragweeds, corn, and apples, may also fall upon the same pistil. But the pollen from plants so distantly related as corn and apples will not fertilize the eggs of the summer squash. Summer-squash and pumpkin plants, however, will each fertilize the other. New organisms that are thus produced by the crossing of related but different kinds are called *hybrids.*

These statements illustrate the fact that distantly related plants and animals cannot be crossed. But closely related plants and animals may unite, even though they do not belong to the same species or sometimes even to the same genus. There is no hard-and-fast rule regarding the extent of relationship over which crossing may occur.

When summer-squash and pumpkin plants are crossed, one might expect that one half of the total number of the resulting fruits would be pumpkins and one half would be summer squashes. One would be wrong. It is the egg from one kind of plant and the sperm from another kind of plant which have united. Therefore the plant thus produced has some of the characters of each parent plant. That is to say, it is neither a pumpkin nor a summer squash. It is a hybrid.

One of the best-known and most useful animal hybrids is the mule. It is produced by crossing the female horse and the male donkey. It is possible, but unusual, to use the opposite cross. The mule has many of the characteristics of the donkey, but has more nearly the size of the horse. It has greater endurance for work, extremes of temperature, and other hardships, is more sure-footed, and can live on rougher food than the horse.



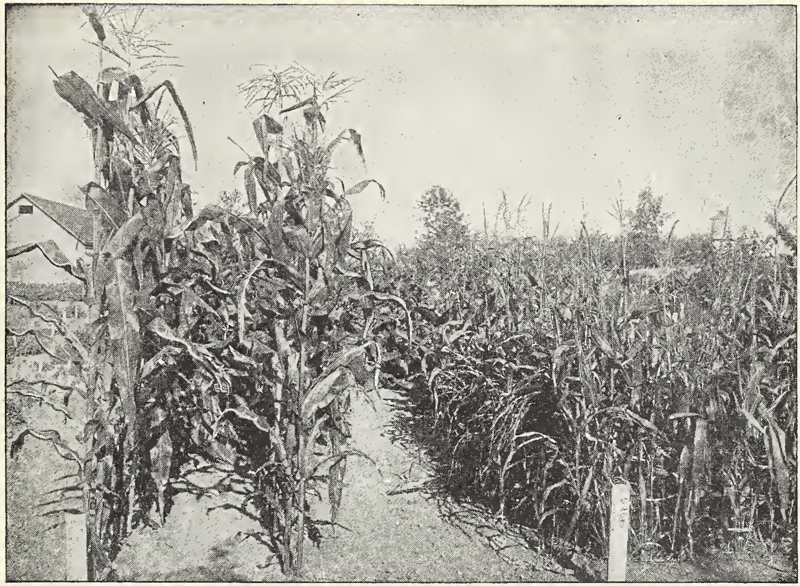
United States Department of Agriculture

A hybrid cross between Aberdeen Angus and Hindu (Guzerat) cattle. **Special Report:** Hybrid cattle. (See United States Department of Agriculture, *Technical Bulletin No. 417* and yearbook (1934), and *Separate Bulletin No. 1561* (1937))

A hybrid usually resembles its parents sufficiently to make its relations to them fairly clear. Yet usually it is obviously different from either. A hybrid may be either superior or inferior to both its parents in some of its qualities. Plant and animal breeders are constantly watching for hybrids that possess superior qualities.

Certain plant and animal hybrids rarely or never produce offspring. The mule is an example. There are only about half-a-dozen known cases in which mules have produced mule colts.

Differences produced by surroundings. It should be clear to all that some of the differences found in organisms of the same kind are not due to inheritance but are due (1) to nutrition, (2) to use, or (3) to various other conditions of the environment. Thus one twin brother may become an artist and the other a blacksmith. As a result of the differences in the kinds of work the two men do, they will become more and more different in physical development. If two plots of corn from the same stock are planted in places as much alike as possible in every way, one with many plants crowded into the area, the other with few plants, the crops from the plots will be very different.



Dr. A. F. Blakeslee

What environmental factors might account for the differences between these two plots of corn grown from the same stock?

Animals of the same ancestral[1] stock will develop very differently if kept under conditions which are similar except that one or more of the food factors are different. But similar care will fail to produce similar animals if the inherited characters of the animals are very different.

*It must be clear that the ancestral stock determines what are the possibilities of development of new organisms. But such environmental factors as food, light, water, space, sunshine, disease, and relation to enemies determine whether the inherited possibilities are developed. Even the best environment cannot produce superior organisms from individuals which carry no good ancestral stock. It is equally true that the best heredity cannot produce superior individuals in an environment which is wholly unfavorable to proper development. Knowing this, the wise animal-breeder or plant-breeder secures the best breeding stock he can find and then gives it the best care he can.

Self-test. 1. Twins are *often* exactly alike.

2. Differences in weight furnish an example of *variation*.

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[1] ***Ancestral*** **(ăn sĕs'trăl): having to do with parents, grandparents, and other ancestors**

3. Variations are *never* of great importance in the struggle for survival.

4. Such marked variations between one generation and the next as changes in the number of toes are known as *hybridizations.*

5. Slight *mutations* may be observed in the offspring of almost every kind of animal or plant.

6. It is not *likely* that rose plants and cabbage plants could be successfully crossed.

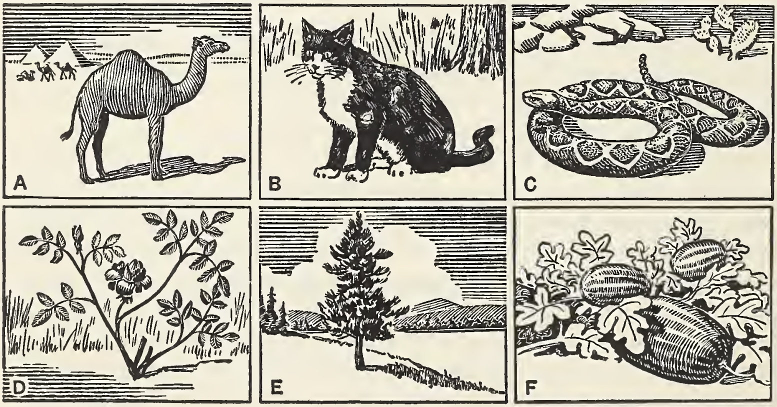
7. A cross between a dog and a wolf would be an example of a *mutant.*

8. The environment has *little* influence upon the development of an organism.

9. Heredity has *little* influence upon what the adults of the next generation will be.

IN WHAT RESPECTS IS THE CELL THE BASIS OF INHERITANCE?

What one cell carries. We have seen many illustrations of the fact that each living thing has grown from one cell. It must be true, then, that all the hereditary[1] qualities, or characters, of each living thing were held in that one cell and that they have developed from that one cell. Why a particular fertilized egg cell grows and becomes a horse and not an oak tree or a small insect seems hard to understand, and especially so when we remember that the fertilized egg cell of even a large animal may be so small that it must be magnified two or three hundred times before it can even be seen. Yet this small



Each of these plants and animals grew from a single cell. Is this also true of simpler plants and animals? Self-test on Scientific Principles: Can you select from the list of principles on page 626 one that summarizes these facts?

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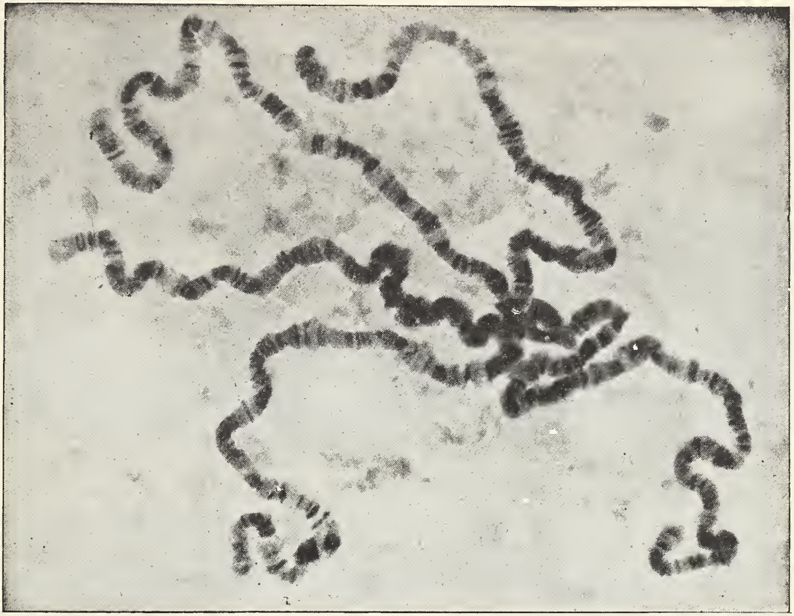
[1] *Hereditary* (hē rĕd'ĭ tĕr ĭ): having to do with inheritance.



Journal of Heredity

Photograph of chromosomes taken through a powerful microscope. Where are the chromosomes and where are the genes in this picture?

fertilized egg contains whatever it is that causes its development to result in a horse, an oak tree, or an insect. In a similar way this cell carries whatever it is that makes the inherited differences between the various kinds of horses, the different kinds of oak trees, and the different kinds of insects.

Such a fertilized egg cell in no way resembles the appearance of the adult plant or animal into which it may grow. Yet structures within it determine what kind of animal or plant it will become. These structures, called chromosomes, are in the nucleus of the fertilized egg cell. Each fertilized egg contains some chromosomes from each parent. Therefore the individual that grows from the egg resembles each parent in certain respects. The number of chromosomes is the same for all body cells of any particular kind of plant or animal. Thus every body cell of the lily always has twenty-four chromosomes; of a certain parasitic worm, two chromosomes; of the crayfish, two hundred; and of man, forty-eight.

The nature of genes. Chromosomes are not simple structures. It is thought that each chromosome consists of many parts and that each part is probably responsible for certain hereditary characters. These parts, or units, are called genes (see the Glossary). One pair of genes may control body color, another may control eye color, each one of other pairs may control form of nose, ear, chin, thumb, body height, tendency to be fat or any other of the many hundreds of hereditary characters. Possibly one gene may control more than one character. The entire theory of genes is relatively new and is receiving much careful study.

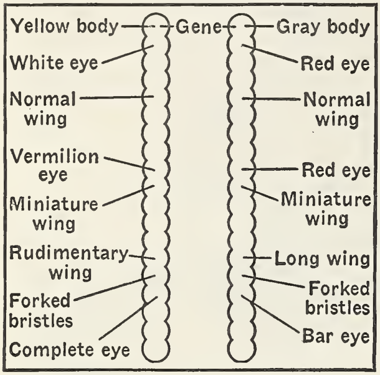


Diagram of a pair of chromosomes of the fruit fly (*Drosophila*). The location of the genes named here has been determined by many experiments. What facts concerning genes can you infer from this picture?

Division in body cells (mitosis). In order that an organism may grow or that new cells of any kind may be formed, it is necessary for cell division to take place. The chief structure concerned in cell division is the nucleus. Within the nucleus of every cell there is material (chromatin) consisting of small grains. As the nucleus of any cell starts the process of division (mitosis), this material combines and forms a ribbon, or band. This band soon can be distinguished as composed of short rods, which are the chromosomes. When the cell is in process of dividing, each chromosome splits lengthwise. The newly formed chromosomes are drawn to opposite ends of the cell, one half to each end. These now form two new nuclei. Each one of these nuclei is composed of as many chromosomes as were in the parent cell. The cytoplasm[1] is then divided by a new cell wall. Thus are formed two new cells exactly like the original one. In due time the new cells may in their turn divide, as their parent cell did.

Division in sex cells (reduction division, or meiosis). It is easy to see that by the process of cell division the number of chromosomes in all the cells of an organism is kept the same. It might be expected, therefore, that when a sperm nucleus and an egg nucleus unite, the chromosome numbers would be doubled in the fertilized egg. But a peculiar occurrence prevents this doubling of chromosome numbers. In one of the stages in the development of sperms and eggs the chromosomes do not split. Instead the chromosomes, without splitting, are separated into two groups at opposite ends of the cell. Therefore, when the cell completes its division into two cells, the new nuclei

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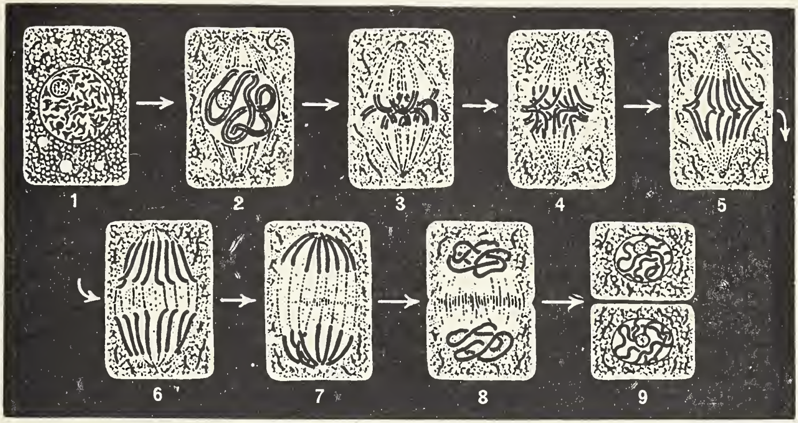
[1] See the Glossary.



Cell division (by mitosis). Organize a short report to explain this figure

of the sex cells contain one half the number of chromosomes that are found in the body cells. Later, when an egg is fertilized by a sperm, and the nucleus of the egg has united with the nucleus of the sperm, the chromosome number is again the regular number of the body cells. Thus the fertilized egg has received half its chromosomes from each parent.

It must be kept in mind that the chromosomes carry the inherited characters. But the fertilized egg does not carry all the characters of both parents, since only half of the chromosomes of each parent cell were used in forming the nucleus of the fertilized egg. It does, however, include chromosomes that carry some qualities from each parent. Furthermore, since both parents once came from their parents in the same manner, and since their chromosomes carried the characters of their ancestors, it follows that the young generation has chromosomes that have been derived in part from many generations of ancestors.

Genes, variation, and mutation. Since the two sets of chromosomes that are in a fertilized egg have come from different parents, it is clear that new hereditary combinations exist in each new organism. The only exception to this statement occurs when, during the early development of a fertilized egg, the cells are completely separated into two or even more groups, each of which develops into a separate individual. Such a division results in identical twins or triplets or very rarely in quadruplets or quintuplets.

You have doubtless noted that twins are of two kinds. There are those which are of the same sex and resemble each other very closely in many ways.

Lynwood M. Chace

These are probably identical twin fawns. Explain "identical twins." The mother deer has left her fawns in order to feed. They will remain quietly until she returns, however long she remains away. What survival values are there in this behavior of the young deer?

These have both developed from the division of a single fertilized egg. They therefore have the same kinds of genes in their chromosomes. Then there are twins which resemble each other in about the same ways as other brothers and sisters. These have developed at the same time from two fertilized eggs. The variations are produced by the different genes in the chromosomes, just as in brothers and sisters of different ages. Variation between related living things is to be expected, since different combinations of genes produce different individuals.

Experiments have been conducted in which the reproductive cells were treated with X rays. If the cells are thus treated too severely or too long, the chromosomes may be killed. If, however, they are treated carefully and for a short time, some of the genes are destroyed, though the whole chromosomes may not be killed. The union of a sperm and an egg, thus treated, is likely to result in a mutant, since some genes which the chromosomes of the parents originally carried will not appear in the next or in succeeding generations.

It has also been found that chromosomes sometimes may become tangled with one another or attached to one another. At such times it is thought possible for genes to become transferred from one chromosome to another, or for various combinations of genes to be made. Such occurrences would, of course, make differences in the hereditary characters appearing later in the organism. Therefore variations result not only from combinations of the genes that come from the two parents but also sometimes from shifts of the genes within the chromosomes.

Self-test. 1. The structures within a fertilized egg which determine what the developing plant or animal shall be are called *chromosomes.*

2. A human embryo has received an *equal* number of *chromosomes* from both parents.

3. The units of which chromosomes are supposed to be composed are known as *chromatins.*

4. One identical twin has *different* hereditary traits *from* those of his brother.

5. Sometimes variations are thought to result from exchanges of *chromosomes* between *genes.*

WHAT ARE THE LAWS OF INHERITANCE?

Strong and weak genes. If a man has brown eyes, and if all his ancestors for many generations have had brown eyes, then all his chromosomes carry genes for that color of eyes. Likewise, if a woman has blue eyes, and if all her ancestors for several generations have had blue eyes, then her chromosomes carry the gene for blue eye color. A child of this man and this woman will inherit genes for both colors of eyes. The eyes of this child, however, will not be part brown and part blue. Neither will they be of a color between brown and blue. They will in this case be brown.

This case illustrates the fact that genes of corresponding characters differ in strength or influence. Usually one character prevails over the other. In such a case the stronger character is called dominant, and the weaker one is called recessive. Thus the dominant character is seen in the offspring and the recessive one is not.

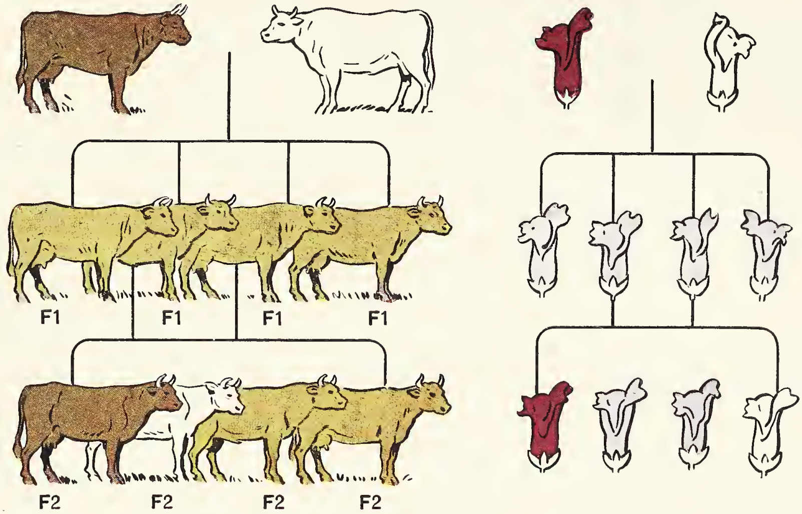
Laws of inheritance. The discovery of some important laws of heredity which govern such cases as that just cited was made in the beginning of the second half of the nineteenth century by Mendel, an Austrian monk. As a result of experimenting with garden peas, Mendel found that such characters

Mendel in his garden. **Special Report:** The scientific work of Mendel

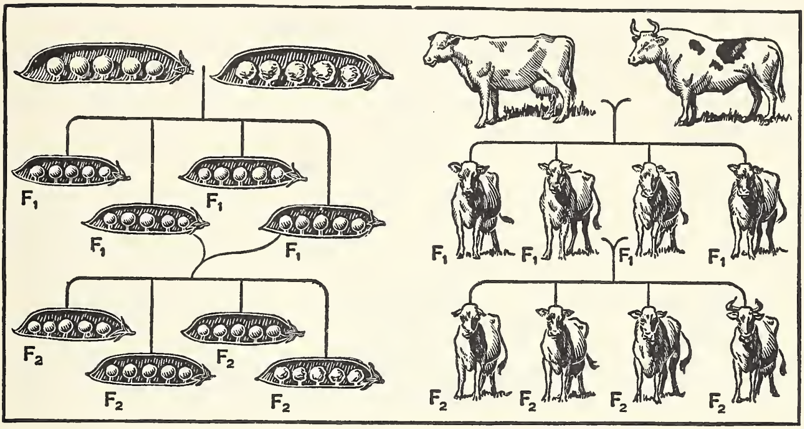
as tallness, shortness, smooth seeds, or wrinkled seeds bred true from generation to generation if the parent peas were grown and kept separate from one another. He first made sure that he had produced pure strains of pea plants for contrasted characters, such as green and yellow, smooth seeds and wrinkled seeds, tallness and shortness, and the like. Mendel then crossed plants with contrasting characters in order to produce hybrids. Thus he crossed tall with short plants, those having smooth seeds with those having wrinkled seeds, and so on.

When he crossed tall with short plants, Mendel found that all the plants in the next, or F_1[1], generation were tall. Mendel concluded that the character tallness is stronger than the character shortness. He therefore called tallness a dominant character, and shortness a recessive character. Among the facts he established by similar experiments are that the character smoothness is dominant over the character wrinkledness in the seeds; yellow is dominant over green in the cotyledons; green is dominant over yellow in unripe pods; and red is dominant over white in flowers.

[1] The symbol F_1 means the first filial, or daughter, generation, that is, the first generation of offspring. The F_1 generation is really the second generation if one counts the parents as the first generation.



Incomplete dominance. State which of Mendel's laws these drawings illustrate. Are the white cow and the white snapdragon in the F_2 generation pure for the character whiteness? Explain

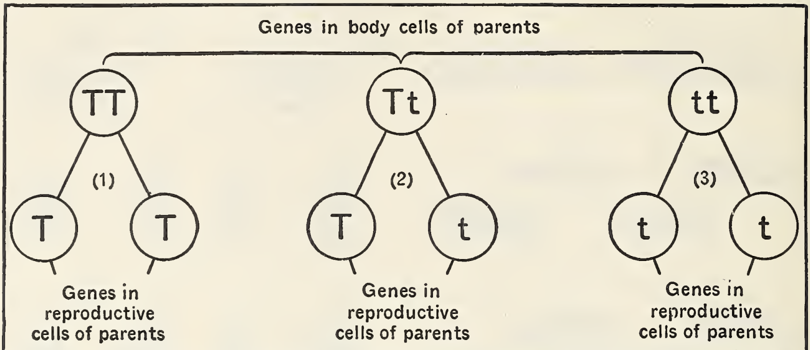


Crossing smooth and wrinkled peas, and horned and hornless cattle. Explain the results in the F_1 and F_2 generations

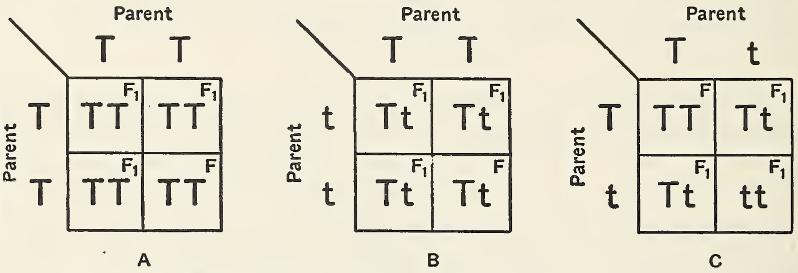
Mendel experimented further to find whether recessive characters would appear again in succeeding generations. He crossed with one another the tall hybrid peas of the second, or F_1, generation which had been produced by crossing the pure-bred tall and pure-bred short parents. We must keep in mind that in these hybrid plants the genes for shortness are present but that the genes for tallness prevail over them. In the third, or F_2, generation Mendel found that approximately one fourth of the plants were short like the short grandparent and that approximately three fourths were tall like the tall grandparent.

In similar experiments regarding the others of seven contrasted characters Mendel found about the same proportions between the dominant and recessive characters in the third, or F_2, generation. That is, in the third generation of such hybrid crosses the recessive character reappears in approximately one fourth of the cases, and the dominant character in approximately three fourths of the cases.

By crossing with one another the F_2 recessive-character plants, that is, the short plants, Mendel secured nothing but recessive-character plants, or short plants, in succeeding generations. It was clear that the recessive character alone was present in these F_2 plants; that is, they were pure short plants and would breed true as short plants. But when the tall plants of the F_2 generation were crossed with one another, the succeeding generations consisted of some tall and some short plants. These results showed that the tall plants of the F_2 generation were not all pure tall plants, but that some at least of the tall plants were hybrids.


Genes in body cells of parents
TT
Tt
tt
(1)
(2)
(3)
T
T
T
t
t
t
Genes in reproductive cells of parents
Genes in reproductive cells of parents
Genes in reproductive cells of parents

Possible combinations of characters in parents: (1) only dominant characters; (2) both dominant and recessive characters; (3) only recessive characters



A

	T	T
T	TT F_1	TT F_1
T	TT F_1	TT F

B

	T	T
t	Tt F_1	Tt F_1
t	Tt F_1	Tt F

C

	T	t
T	TT F	Tt F_1
t	Tt F_1	tt F_1

Diagram showing the results of crossing tall with short individuals. A, if both parents carry only genes for tallness (T), all their offspring (F_1) will be tall. B, if one parent carries genes for tallness (T), while the other carries genes for shortness (t), all their offspring (F_1) will be tall hybrids because tallness is dominant. C, if both parents are hybrids, that is, have genes for both tallness (T) and shortness (t), one fourth of their offspring will be pure tall, one half will be hybrid tall, and one fourth will be pure short. Draw figures similar to these to illustrate 3, *b*, and 3, *c*, of Mendel's laws, p. 607

Later experiments have proved that the F_2 generation consists of approximately one fourth pure tall plants, one fourth pure short plants, and one half hybrids. These proportions would usually be strictly correct only when large numbers are considered. In many cases, however, the proportions have been found true even when small numbers of individuals were used.

Summary of Mendel's laws. Mendel's experimenting resulted in these laws of heredity:

1. *Law of unit characters.* Unit characters will breed true from generation to generation if the parent stock is pure for this character.

2. *Law of dominance. a.* When an individual which is pure for a certain character (for example, tallness) is crossed with another which is pure for a contrasting character (for example, shortness), the offspring will all have the one of these characters (tallness) which is dominant over the other.

b. These offspring are all hybrids which carry the genes of the recessive character as well as those of the dominant one.

3. *The law of segregation.* The unit characters do not unite, or blend, but remain as individual factors in the genes.

a. When hybrids are mated, approximately 25 per cent of the offspring are pure dominant, 25 per cent pure recessive, and 50 per cent hybrid.

b. When pure dominants are mated with hybrids, approximately 50 per cent of the offspring are pure dominant, and 50 per cent are hybrid.

c. When pure recessives are mated with hybrids, approximately 50 per cent of the offspring are pure recessives, and 50 per cent are hybrids.

Further illustrations of inheritance. Since Mendel's results were first made public, many experiments have been made. These have confirmed the principles of inheritance which he established. For example, when Mexican black corn and white corn are crossed, the ears of the hybrid plants which result will have about three times as many white grains as black grains because white is here dominant over black. In the cases of some inherited characters it is now known that the genes are equally potent or nearly so, with the result that neither is completely dominant nor recessive. Thus the children of Negro and white parents are usually less dark than one parent and darker than the other. Red and white cattle when crossed produce roan offspring.

Are acquired characters inherited? If white cats were frequently washed and kept white, the washing would in no way increase the chances that their kittens would be white. Or if these white cats were frequently dipped in black or red ink, that treatment would in no way change the color of their kittens born later. The color inheritance could be changed only by changing the genes in the chromosomes of the sex cells.

*We may select individual plants or animals that are particularly well suited to our needs and wishes, and may keep these selected individuals in the best possible environment; but they transmit to their offspring only the characters they themselves inherited. They cannot to the slightest extent transmit to their offspring any character as it has become modified as a result of the care which they themselves received. Thus young sheep have long tails, but as a sanitary measure farmers for many centuries have cut off their tails. However, lambs continue to be born with tails undiminished in length. Many other illustrations may be cited which show that changes in characters resulting from experience are not transmitted.

Skills resulting from practice are not inherited. For example, a great tennis-player may practice and play for years. His children will not, however, inherit his ability to play tennis, though they may inherit from him the qualities that will permit them to become good tennis-players. Again, we sometimes hear it said that ability to perform excellently in music is inherited. The several generations of musicians in the famous Bach family are cited as proof. But it was not the musical skills that were inherited; it was the musical talent, that is, the capacity or ability to learn music. The encouragement of music given by the home and community environment helped to develop the transmitted capacity.

Some people believe that a woman can mold the characters of her children by controlling her own thoughts and actions before the children are born. Thus she will read poetry and listen to good music under the belief that by so doing her children will have poetic or musical talent or will have noble characters. Also, some people believe that a bad fright or a shock experienced by a mother before the birth of her child may cause the child to be born with birthmarks or with some mental or physical defect. All beliefs of the kinds just mentioned, however, are entirely without scientific foundation.

Under certain conditions it is possible for the environment to affect the genes of the sex cells. When this occurs, the offspring will differ from their parents. For example, fruit flies which have been treated with X rays sometimes have the genes for eye color destroyed. Their offspring therefore have white eyes, that is, eyes lacking color. Plants which were treated with certain chemicals developed twice the usual number of chromosomes in their seeds. This mutation produced plants which differed in appearance from the parents.

From the examples cited in the preceding paragraphs, and many others that might be cited, it is now known (1) that in general, acquired characters are not inherited and (2) that the environment of an individual may affect its offspring only if the environment can produce changes in the reproductive cells.

Self-test. 1. Some important early scientific investigations of the laws of inheritance were carried on by (1) Tyndall, (2) Mendel, (3) Burbank, (4) Pasteur, (5) Lister, (6) Aristotle.

2. If garden peas with red flowers are crossed with garden peas with white flowers, *one half* the plants in the F_1 generation will have white flowers, and *one half* in the F_2 generation will have white flowers.

3. All the offspring of two black cats *will* be black. Explain.

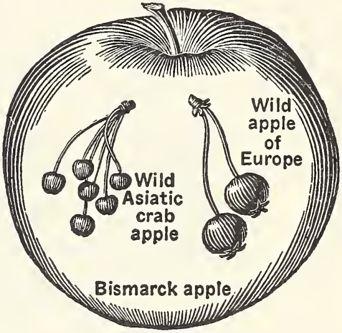
4. It would be *impossible* for the offspring of animals having distinct colors to be of a shade somewhere between the colors of the parents.

5. If all kittens had their tails cut off, the kittens of *some* future generation would be born without tails as a result of this treatment of their ancestors.

6. Unusual experiences of a mother before the birth of her child are believed by scientists to have *little* effect upon the bodily appearance of the child.

HOW DO MEN APPLY THE LAWS OF INHERITANCE?

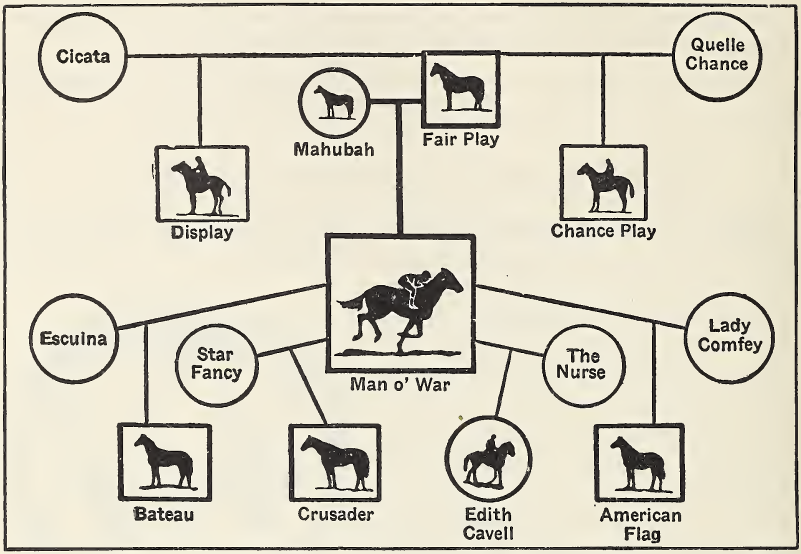
Selection and development of the best. Man's applications of the known laws of inheritance have produced great improvements both in the quality and in the quantity of the plants and animals upon which men depend. Most of our domestic plants and animals have been developed from smaller or otherwise less desirable wild varieties. Corn was cultivated by the Indians before the white men came to America. Probably the Indians had, by selecting good ears for seed, produced corn somewhat different from the original wild variety and probably somewhat better. But the Indian corn had short ears and small grains. By careful selection, crossing, improved cultivation, and continuous care in using the best types for succeeding years, man has produced superior varieties of corn with large ears and grains.



A comparison of the size of the modern apple with its ancient ancestor, the wild apple of Europe. Can you name other plants that have been improved?

Recently greatly improved varieties of many kinds of plants have been produced by a special method of selective breeding. By this method flowers are artificially pollinated with pollen from other flowers on the same plant. This process of "inbreeding" is repeated for several generations. Finally pure strains having desired characters are selected. From these selected plants, those having unlike characters are crossed. The resulting hybrids often have unusual and especially valuable qualities. For example, a new variety of corn has thus been produced, a single plant of which bore thirty-six unusually large ears. Another hybrid corn has been developed which has large heavy ears and strong stalks that are little affected by winds or by insects.

One of the significant achievements of modern plant-breeding and animal-breeding has been the development of types immune to certain diseases. For example, in a wheat field that was badly infected with rust a few stalks that were not affected were discovered. The grains of these plants were saved and



The horses pictured in black were famous race horses.[1] Explain how this diagram shows that desirable traits are inherited

planted. Fortunately they bred true for this character of resistance to rust. It has since been possible by crossing this type of wheat with other desirable types to produce wheat which gives a high yield per acre and is also less affected by rust than other wheat. In a similar fashion man has produced corn which is immune to smut, cabbage which resists the disease known as the yellows, and potatoes which are immune to blight.

Partial success has similarly been achieved in producing animals immune to certain diseases. Texas fever kills thousands of cattle every year. It was found that certain cattle from India are immune to the fever. By crossing the Indian cattle with common cattle a variety has been produced which is a good beef animal and is also immune to Texas fever.

*The methods of the plant-breeder or animal-breeder include (1) improving known species by selecting and breeding desirable types, (2) producing new types or new varieties which may possess entirely new combinations of characters, and (3) preventing the breeding of undesirable types. Luther Burbank used all these methods in producing the many improved types of plants which he gave to the world. In a field of thousands of plants he often found only two or three which possessed any indication of the desired characters. These he kept for further breeding. All others he destroyed. Thus by selective breeding through a period of years Burbank produced many of our choicest and most valuable fruits, flowers, and other useful plants.

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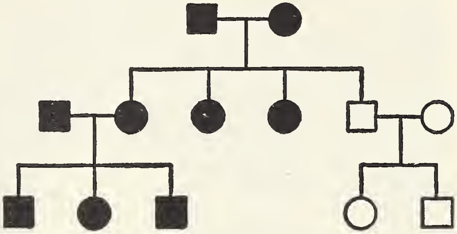
[1] From Caldwell, Skinner, and Tietz's *Biological Foundations of Education*, Ginn and Company.

Use of pedigrees. A breeder who wishes to know more about a plant or an animal than can be seen merely by looking at it finds a written record of its ancestry desirable. Such a record, or pedigree, usually includes facts about several of the characters regarded as most important for the animal or plant concerned. The pedigree of a particular kind of wheat gives the record for each generation regarding such qualities as number and kind of grains, total yield, vigor of the growing wheat plant, and its resistance to disease, drought, or cold. The pedigree of a draft horse deals with such important characters as weight, form, disposition, endurance, and working qualities. The pedigree of a race horse deals with speed, endurance, disposition, and action during races.



A study of feeble-mindedness. Circles represent females; squares represent males. White circles and squares indicate persons of normal intelligence. Black circles and squares indicate feeble-minded persons. How does this representation of a family prove that feeble-mindedness is inherited?

Nearly all kinds of animals and plants used in man's domestic life are now pedigreed in one way or another. Plant pedigrees, however, have not been developed so extensively as animal pedigrees, though people are coming more and more to recognize their importance.

Mendel's laws and human inheritance. *As was indicated earlier, the transmission of human qualities occurs according to the same principles that govern inheritance in lower animals and in plants. Many aspects of human inheritance, like many of animal and plant inheritance, are not yet fully understood. But many facts of the greatest importance are definitely known. A good illustration is found in the inheritance of feeble-mindedness and of normal-mindedness. Normal-mindedness is usually a dominant character, and feeble-mindedness is usually recessive. Children of a feeble-minded parent and of a normal parent who has no feeble-minded ancestry almost always appear normal. All such children, however, are really hybrids between these contrasted characters. When these hybrids later become the parents of a third (F_2) generation, the feeble-mindedness is likely to appear.

Six feeble-minded members of one family.[1] How would you explain the meaning of this picture to one who had not studied biology?

Many other undesirable mental characters are associated with hereditary physical defects. It is now thought that undesirable traits such as may result in criminality, that is, the tendency to commit serious criminal acts; pauperism, that is, the tendency to do nothing effective toward one's self-support; and tendencies toward vice of various sorts are likely to be inherited. In fact, all these undesirable characters are somewhat related, and all are frequently found in the same family. Still other undesirable traits which "run in families" and are therefore hereditary include epilepsy, some forms of insanity, hunchback, fingers lacking the normal number of bones, harelip, cleft palate, deaf-mutism, some forms of blindness and deafness, and physical weaknesses which make the individual likely to contract certain kinds of disease.

*But the inheritance of desirable traits is just as certain as the inheritance of undesirable traits. Many superior characters are known to be hereditary. There are records of families in which for several generations members have been noted for their achievements in science, literature, art, music, and other fields of worthy endeavor. The mental and physical foundations making such achievements possible are transmitted through the same laws that control inheritance of other qualities.

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[1] From Caldwell, Skinner, and Tietz's *Biological Foundations of Education*, Ginn and Company.

Social implications. *The improvement of future generations depends in a large measure on the selection of good human stock. Everybody should, therefore, be concerned to know the kind of stock from which he is descended. Likewise everybody should be concerned about the quality of the family into which he may consider marrying. Many people are not sufficiently concerned about such knowledge. Consequently some people marry who probably should not. Others marry individuals who, though apparently normal, carry defects in their genes. As a result, in either case, undesirable traits may appear in the children.

The marriage of young people of good stock ensures that the next generation will have a good inheritance. No other possession is so desirable as a thoroughly good biological inheritance.

Among the qualities that a person possesses as a result of his heritage, there are certain to be some which are superior. Some others may be undesirable. There is no way, however, by which a person can change his heritage. But he can do his best to learn what are his desirable and what are his undesirable qualities. He can then make an earnest effort to select and adjust his environment in such ways as to give his best qualities ample opportunity to develop and to suppress his undesirable qualities. Indeed, a person's true strength and his real achievement depend largely on his making the best uses of all his inherited qualities.

Self-test. 1. The laws of inheritance established by the scientific experiments of *Mendel* have been used to produce superior plants and animals.

2. State the methods used by plant-breeders and animal-breeders in their attempts to produce improved varieties.

3. Name at least ten undesirable human traits which can be inherited.

4. Desirable *human* traits, as well as undesirable ones, can be inherited.

5. People are likely to have *only* good *or* bad traits.

6. One's *inheritance* can be changed; one's *environment* cannot be changed.

Self-test on Important Biological Terms

character
chromosome
dominant character
gene
hybrid
mutant
mutation
recessive character
variation

Exercises on Biological Principles. 1. How many instances can you find to illustrate this statement: "New kinds of living things have arisen through mutations"?

2. Give one or more illustrations of this principle: "In plants and animals certain traits are usually dominant, while others are recessive. In other instances neither trait is dominant, with the result that a hybrid offspring has characters between those of its parents."

3. How would you explain these principles to someone who had not studied heredity? (1) "Living things produce offspring which possess the genes of their ancestors, though the offspring do not necessarily resemble any one of these ancestors." (2) "Acquired characters are not transmitted."

4. Could this statement be true: "Pure-bred black mare mated with a pure-black stallion resulted in white colt"? Quote one of Mendel's laws in support of your answer.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. With hogs, white is usually dominant over black. If a white pig and a black pig are crossed, what will be the appearance of the F_1-generation offspring? Will they be pure-bred or hybrid? If two of these pigs of the F_1 generation are crossed, what will be the color of their offspring?

2. Using the facts given here, make up and solve problems similar to 1.

Plants or Animals	Dominant	Recessive
Cattle	Black	White
Cattle	Hornless	Horned
Guinea pigs	Black	White
Horses	Bay	Black or chestnut
Horses	Trotting	Pacing
Hogs	White	Black
Cats	Black	Blue
Cats	Hair short	Hair long
Dogs	Gray	Black
Dogs	Hair short	Hair long
Man	Skin and hair dark	Skin and hair light
Man	Eyes dark	Eyes blue
Man	Hair curly	Hair straight
Garden peas	Flowers colored	Flowers white
Garden peas	Stems tall	Stems short
Garden peas	Seeds smooth	Seeds wrinkled
Garden peas	Seeds yellow	Seeds green
Corn	Yellow	White

3. Suppose you have some dwarf poppies that bear beautiful red flowers; also, tall poppies with white flowers. If you want to produce a tall plant with red flowers that will breed true, how will you secure such a plant?

4. What does it mean to say that a characteristic "skips a generation"? Could it skip two or three generations? Explain.

5. Recently in a litter of kittens was one with an extra toe on each foot. The cat grew up and has since had a number of children and grandchildren with extra toes like itself. Is the cat a freak or a mutant? Explain.

6. How would one determine whether a unit character is dominant or recessive?

7. How could a child of brown-eyed parents have blue eyes?

8. Make a chart showing the inheritance of some characteristic in your family. Hair color, eye color, curly and straight hair, and other such characters are sometimes striking illustrations.

9. Name a variety of plant or animal which did not exist one hundred years ago. How was it developed?

Project 26. To prepare illustrations of common variations. (1) By examination of the leaves of one tree or shrub select and fasten to sheets of paper samples of leaves that differ in any way from one another. How many variations can you find upon any one plant? (2) Examine a litter of kittens or of pups and prepare a chart listing or illustrating all the differences you can find among the individuals of such a litter.

Project 27. To produce hybrid plants by controlling pollination. Plant some field corn and some sweet corn in good soil in a garden or field. Just before the ear (pistillate) flowers and tassel (staminate) flowers open, tie paper bags over the ears so that no pollen may enter except that which is desired. When the stamens are ripe, carefully place pollen from each kind of plant upon the silk of the ears of the other plants and replace the paper bags for two weeks. Then remove the bags and allow the ears to mature. When they are mature, collect all the ears into two lots, remove the husks, and see how many of the grains show the qualities of each kind of parent plant.

Special Reports. 1. Find and present some additional facts about the work of Mendel.

2. Find evidence to support the statement "Most of our food plants and our domestic animals have been developed from less desirable wild varieties."

Questions for Debate. 1. *Resolved,* That the work of Edison has proved to be of greater practical value to the world than that of Burbank.

2. *Resolved,* That the government is justified in restricting immigration to those who are themselves at least normal and who can present a satisfactory pedigree for at least three generations back.

3. *Resolved,* That environment has more influence than heredity over what an organism finally becomes.

Review Exercise on Biological Principles. The following principles have a direct relation to every Victory Garden. Can you explain how each principle applies to the garden? Which of these principles are not stated on pages 626 and 627?

Plants are directly or indirectly dependent on the soil.

All living things have living enemies which compete with them for available energy.

Plants and animals are dependent on one another in various ways.

The work of chlorophyll is essential to all living things.

All plants and animals are engaged in a constant struggle for energy.

Energy and matter cannot be either created or destroyed, but are passed on from organism to organism in endless succession.

All organisms must have water in order to survive.

Water tends to rise through small tubes (such as cracks in the soil).

Plants take in water through their roots and give off water from their leaves.

Green plants make more food than they need and store the surplus food in various structures, such as roots, stems, seeds, and fruits.

During the larval stage insects are active and eat great quantities of green plants.

Green plants grow toward the light.

Plants and animals must have air.

Living things require heat in order to carry on their life processes.

The sun is the source of nearly all the energy on the earth.

If left to themselves, living things in any region tend to establish a balance of nature.

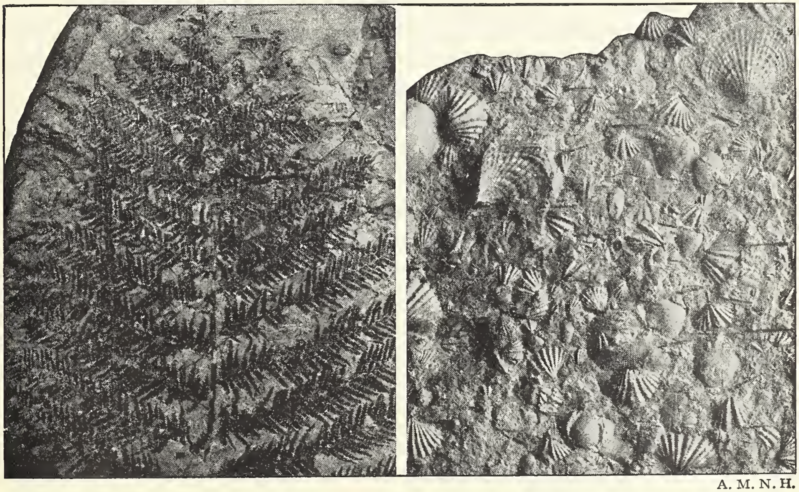
CHAPTER XXX

Records of the Ages

Questions This Chapter Answers. **1.** What are some of the ways in which the surface of the earth is slowly but constantly changing? · 2. What are the various types of fossils and how were these formed? · 3. What kinds of records are made in fossils? · 4. What do coal and fossils tell us about the ancestors of modern plants? · 5. What fossil evidences are there regarding modern animals? · 6. How are recent and present life related to past and future life?

WHY DO SCIENTISTS BELIEVE THAT LIFE NOW ON THE EARTH IS DESCENDED FROM ANCIENT LIFE?

Change always occurring. If you examine the walls of a gravel pit or roadcut, you are likely to find evidence of ancient action by wind or water or both. The sand, gravel, and soil show clearly that they were deposited in layers. Even rocks sometimes show that they were deposited by water currents. Along steep banks or on slopes of hills and mountains one may sometimes see places where great masses of earth have slid downward, sometimes a few feet, sometimes a mile or more. Such sliding masses carry everything with them: soil, rocks, plants of all kinds, even animals, and in rare cases the homes of men. In places where the soil is of sand or loam, strong dry winds sometimes carry away thousands of tons of the earth's surface and deposit it elsewhere.



A. M. N. H.

Fossils. Left, a fern print in coal; right, a rock composed largely of shells. What does each of these fossils tell us about the history of the place in which it was found?

The California tar pits as they are believed to have looked ages ago. How did so many

The earth is always changing. What was a river bottom ages ago may now be part of a fertile field. When it was a river bed, logs, stones, and the bones or shells of animals may have been buried in layers of gravel and sand. When today we dig down into the old river bed, we may find the buried evidences of former life. Thus we may learn some of the facts about the times and conditions in which these things lived.

Records of plants and animals of long ago. Fossils of several kinds help to reveal the world's ancient past. Probably the most common are the shells of snails, clams, and other animals the bodies of which were protected by hard coverings. Others are structures which were replaced by rock as they decayed, bones which have not decayed, occasional animals and plants preserved for thousands of years in ice or in amber, and often such evidences as footprints or worm casts made in mud that later was changed to stone.

The study of fossil shells reveals the fact that they were the coverings of animals related to those that now live on the earth. In general, the older the beds in which the shells are found, the less is the resemblance of the shells to animals now living. But this is not always true. In a few cases very old shells are found that closely resemble those of present-day forms. Such evidences show that animals now living are related to those of past ages.

Near Los Angeles there are ancient deposits which ages ago were pools of tar or pitch. Animals which happened to get into these pools slowly sank and became buried in them. The flesh of the animals was destroyed. The bones, however, remained as authentic history of the animals which inhabited this region during many centuries.

In arctic Russia an ancient mastodon that had become frozen in the ice and thus had been preserved for thousands of years was discovered some years ago by Russian scientists. Most fossils, however, are found in beds of rock that have been deposited throughout long ages while water was carrying mud,

Los Angeles Museum of History, Science, and Art

different animals, especially the carnivorous ones, happen to be caught in the tar?

sand, pebbles, and dead bodies of plants and animals into the deeper parts of the swamps, lakes, and oceans. Such fossils were formed in this way: Sometimes plants and animals were buried in soil which was moist with water in which minerals were dissolved. As the plant and animal bodies decayed, mineral matter from the water was deposited in their tissues. The mineral matter which was thus slowly deposited took the forms of the plant or animal parts it replaced. In this way the petrified trees and the fossil "bones" of animals were formed. Sometimes the deposited minerals took the places of even the softer structures, thus preserving the entire bodies of plants and animals.

Coal, a record of past life. At different times in the past in warm regions of the earth extensive swamps were covered with rank vegetation. As the plants died, they slowly settled into the swamps. Great masses of these fallen plants finally became buried beneath heavy layers of eroded mud and sand. These plant materials were slowly turned to coal, probably partly through the action of bacteria and partly through heat and pressure.

Sometimes the plant structures, such as branches, stems, or roots, kept their original forms, even though they were changed to coal. Sometimes the remains of small animals that had lived among the ancient plants were likewise preserved in the plant layers. By a study of these plant and animal fossils much has been learned about the plants and animals that lived during the coal-forming ages.

The ancestors of modern living things. As stated in Chapter IX, present-day ground pines, or club mosses, and the scouring rushes are the modern descendants of ancient plants which in coal-forming ages were small trees. One of these plants has a name meaning "scale tree" (*Lepidodendron*) because the bark had heavy scales looking somewhat like the scales on an alligator's skin. The tree had no leaves like those seen in modern plants, but the scales served as leaves. The ancient relatives of the scouring rushes reached a height

Buffalo Museum of Science

Some organisms that lived ages ago (Devonian Age) where Buffalo, New York, now is. What evidence is here to support the principles stated on this page?

of not less than twenty feet, but in form and structure they closely resembled the modern scouring rushes. Ancient tree ferns, gigantic in size, were much like the modern tree ferns which thrive in moist tropics. They reproduced in ways quite similar to those of modern ferns.

*From the bits of evidence found in the fossils of various kinds, scientists have been able to piece together, bit by bit, much of the history of living things for several hundred million years. There are still many parts of this history that are not yet known. These are, of course, more numerous and extend over longer periods as the study goes farther and farther into the past. Also, much that is stated concerning the history of living things is still theory because enough evidence has not yet been discovered to establish the truth completely. Yet there is so much evidence that scientists do not now question the truth of the following principles:

1. The earth is very old, probably at least a billion years old and perhaps more than two billion years old.
2. The surface of the earth is slowly but constantly changing as a result of natural laws and processes.
3. The earth was hundreds of millions of years old before life of any sort appeared on it.
4. Plants lived on the earth ages before any animals appeared.

5. All the kinds of plants and animals now living are but a small part of the total number of kinds that have lived on the earth.

6. Things now living have developed from earlier living things.

7. In general, modern plants and animals are more complex than those of ancient times.

8. Energy and matter cannot be either created or destroyed, but they are passed on from organism to organism in endless succession.

Living evidences of ancestry. *There is much evidence besides that found in a study of fossils to show that present living things descended from those of earlier times. There are the facts (1) that the embryos of the different kinds of higher animals appear so much alike, as is shown in the figure on page 574; (2) that the higher animals have corresponding parts, such as head, arms, legs, feet, heart, lungs, digestive systems, and so on; (3) that the higher animals have certain structures which, though poorly developed, correspond to similar well-developed structures in lower animals. Such structures include the appendix in man; the third eyelid (nictitating membrane) of the frog; gill openings, which in the higher animals appear only in the embryo stage but which in the lower animals are well developed and useful in the completely developed individuals; the pineal gland, which corresponds to the "third eye" of certain lowly, ancient, mud-burrowing fishes.

The evidences secured from various scientific fields have made it possible for scientists to find the relationships of the organisms now living not only to one another but also to those which once lived but long since became extinct.

Living things past, present, and future. Science in its never-ending search for truth is constantly throwing a clearer light upon the procession of living things through the ages. Each year adds to what is known of animals and plants of the past. Each year adds to what is known of the relation of past life to that now upon the earth. The plants and animals now living take on added significance when we consider them as the present representatives of long ages of development of life on the earth. Those now living, like ourselves, are merely the individuals through which past life and future life are connected.

Change follows change through succeeding ages. Changes in living things will continue to be brought about, probably to an increasing extent by man. Other changes in plants and animals will result from changes in climate and from other factors. Forms now abundant may disappear, and new ones may take their places, as has occurred frequently during the age-old development of plants and animals on the earth. But the struggle for existence will continue without pause.

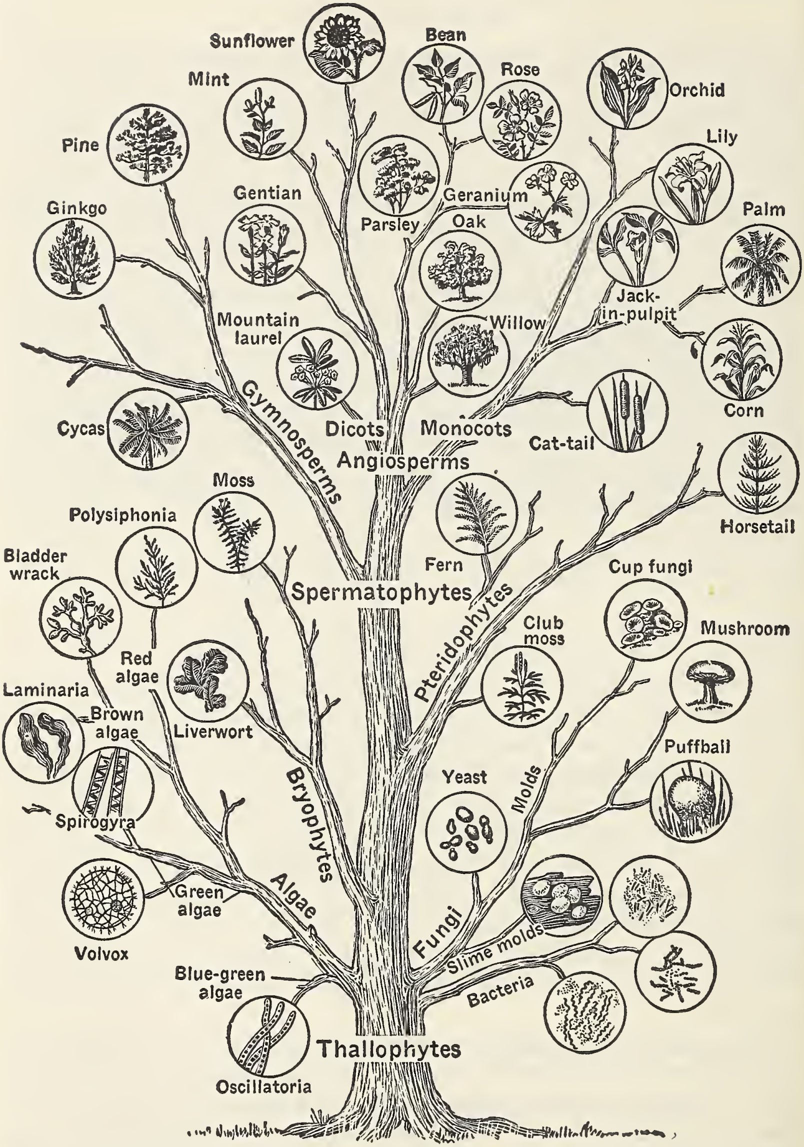


Diagram showing how plants are related.[1] The undiscovered common ancestor of two or more known forms is sometimes called a "missing link." Can you explain this term?

[1] After Gruenberg's *Biology and Human Life,* Ginn and Company.

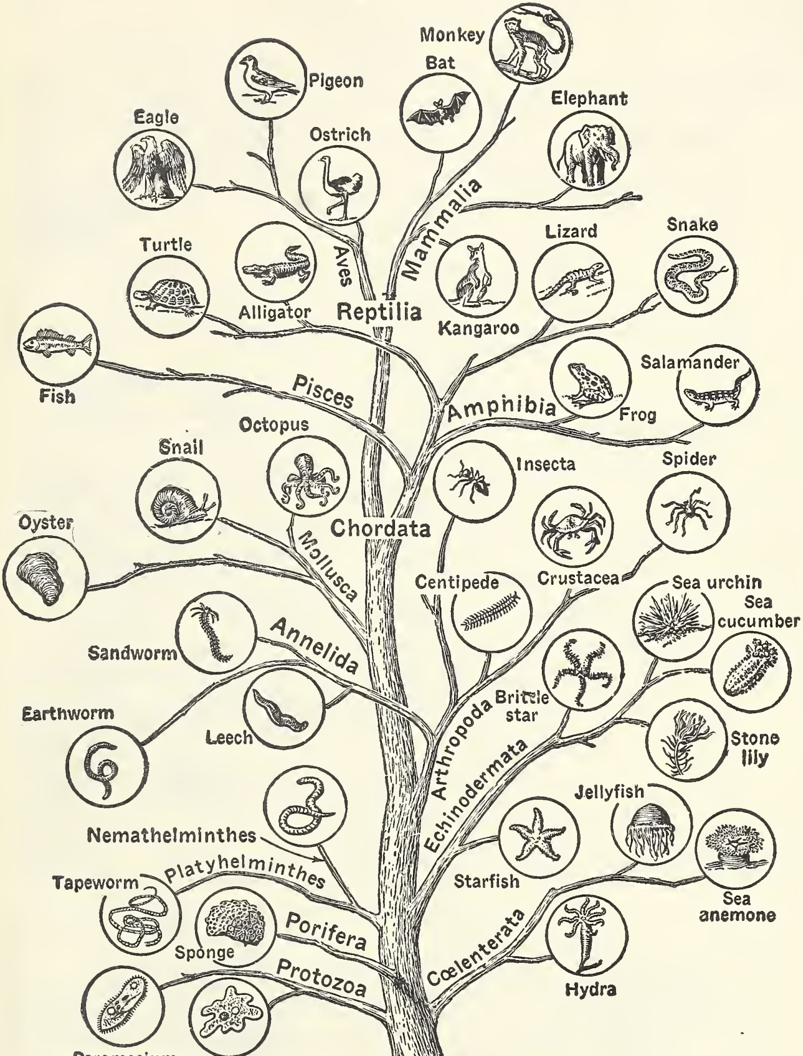


Diagram showing how animals are related.[1] Some biologists place *Volvox* on the animal tree; here it is put on the plant tree. How do you account for this difference in classification?

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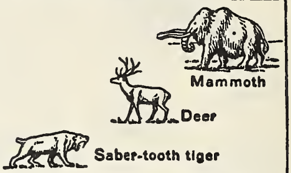
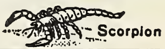
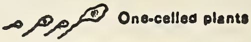
[1] After Gruenberg's *Biology and Human Life*, Ginn and Company.

Per Cent of Total Time	Era	Age	Geological Period	Dominant Types of Life
0.2	Psychozoic	Age of Man	Recent	
	Cenozoic At least twenty million years ago	Age of Mammals	Pleistocene	
1.9			Pliocene	
			Miocene	
1.9			Oligocene	
			Eocene	
5.0	Mesozoic At least seventy-five million years ago	Age of Reptiles	Cretaceous	
3.75			Jurassic	
2.25			Triassic	
3.0	Paleozoic At least two hundred and twenty-five million years ago	Age of Amphibians	Permian	
6.0			Pennsylvanian	
			Mississippian	
4.5		Age of Fishes	Devonian	
3.0			Silurian	
7.5			Ordovician	
6.0			Cambrian	
25.0	Pre-Cambrian At least five hundred million years ago	Age of Invertebrates	Proterozoic	
30.0			Archeozoic	

Can you explain this chart, constructed from a study of fossils?

It is certain that those who study biology some thousands of years hence will find somewhat different biological materials from those available for study today. The possession of scientific attitudes and the use of scientific methods, however, will prove as valuable and necessary then as now. New facts will be discovered and old ideas will be changed as biological knowledge increases. But the principles of biology are likely to remain unchanged.

Self-test. 1. Name at least four different types of fossils.

2. In general, the deeper a fossil is buried, the more *ancient* it is.

3. *Large* animals and plants were on the earth long before *small* animals and plants.

4. *No* forms of life now on the earth are larger than the ancient animals.

5. State some of the evidences which lead scientists to believe that present living things are descended from ancient living things.

6. *Animal* life is believed by scientists to have been on the earth before *plant* life.

Self-test on Biological Principles. State evidence from the chapter which will support each of the principles found on page 625.

ADDITIONAL EXERCISES AND ACTIVITIES

Problems. 1. Do you know of places which prove that conditions used to exist that are different from those of the present? Give your evidence.

2. Under what conditions could fossils be forming today?

Reference Books

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JEWETT, F. G. *The Next Generation.* Ginn and Company, Boston.
LUCAS, F. A. *Animals of the Past.* American Museum of Natural History, New York.
OSBORN, H. F. *Men of the Old Stone Age.* Charles Scribner's Sons, New York.
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SINNOTT, E. W., and DUNN, L. C. *Principles of Genetics.* McGraw-Hill Book Company.
SNYDER, L. H. *Principles of Heredity.* D. C. Heath and Company, Boston.

Motion-Picture Films

The Living Cell. Eastman Kodak Company, Rochester, New York.
Plant Growth. Erpi Picture Consultants, New York.
Seeds and Seed Dispersal. Erpi Picture Consultants, New York.
Development of the Bird Embryo. Eastman Kodak Company, Rochester, New York.
Sexual Reproduction. Scientific Film Company, Daytona Beach, Florida.

SCIENTIFIC ATTITUDES, ELEMENTS OF SCIENTIFIC METHOD, AND BIOLOGICAL PRINCIPLES

Scattered *through this book are many references to Scientific Attitudes, Elements of Scientific Method, and Biological Principles. These very important aspects of the study of biology are grouped for your convenience on this and the following three pages. These groups will serve for ready reference and will provide a useful means by which you can review and test your understandings of the work of the course.*

SCIENTIFIC ATTITUDES

1. A curiosity to know about one's environment.

2. The belief that nothing can happen without a cause and that occurrences that seem strange and mysterious can always be explained by natural causes.

3. An unwillingness to accept as facts any statements that are not supported by convincing proof.

4. The determination not to believe in superstitions of any sort.

5. The belief that truth itself never changes, but that our ideas of what is true changes as we gain more and more knowledge.

6. An intention not to experiment blindly and carelessly, but to begin work only after careful planning.

7. The determination to be careful and accurate in all one's observations.

8. A willingness to consider all the evidence and to try to decide whether it really relates to the matter which is being considered, whether it is sound and sensible, and whether it is complete enough to allow a conclusion to be made.

9. A determination not to base final conclusions on one or a few observations, but to work as long as may be necessary in order to secure an answer to a problem.

10. The desire to do one's own observing and experimenting, but a willingness to use the results of other scientists' work.

11. The willingness to change an opinion or a conclusion if later evidence shows that it is wrong.

12. The intention to respect another's point of view.

13. The determination to prevent one's own likes and dislikes from influencing one's judgment.

ELEMENTS OF SCIENTIFIC METHOD

1. Locating problems for study.

2. Inventing and carefully planning experiments and investigations to solve problems.

3. Using controls, that is, performing along with the original experiment part or all of it in a way that is different from it in only one respect. By using controls the experimenter knows that his results are not due to chance.

4. Isolating the experimental factor, that is, making certain that there is only one factor or condition different in the original experiment and the control experiment.

5. Making careful observations.

6. Making check experiments, that is, repeating the same experiment or observations, or performing or making new ones, in order to be sure that the results obtained from the earlier experiments and observations are correct.

7. Making inferences, hypotheses, or generalizations from given facts or observations, that is, making the best explanation or prophecy one can from the facts known.

8. Studying conditions or experiments described in order to detect any errors or defects that may be in them.

9. Evaluating procedures, data (facts obtained), and conclusions, that is, judging the values of each of these parts of the experiment.

What evidence can you cite from any portion of the book which will seem to add proof to each of the following principles?

1. From lower to higher forms of life there is an increasing complexity of structure, and this is accompanied by an increasing division of labor.

2. The energy which makes possible the activity of most living things came at first from the sun and is secured by the organism through the oxidation of food within its body.

3. Species not fitted to the conditions about them will not thrive and finally will become extinct.

4. Certain associations of plants and animals are the result of a struggle for survival—for example, community or social life, parasitism, and symbiosis.

5. There is scarcely a region on the earth's surface where some form of life does not exist.

6. Life exists from the depths of the ocean to the mountain heights.

7. Life may exist under conditions of light ranging from bright sunlight to the darkness of caves.

8. Living things have become adapted to wide ranges of physical conditions.

9. Plants and animals are directly or indirectly dependent on the soil.

10. Green plants depend on non-green plants for certain materials necessary in food-building.

11. Energy and matter cannot be either created or destroyed, but are passed on from organism to organism in endless succession.

12. Living things may exist under conditions of temperature ranging from many degrees below 0° C to nearly the boiling point of water.

13. All living creatures have living enemies which compete with them for available energy.

14. Living things resemble their parents in general, but vary from them in some respects.

15. Plants and animals are dependent on one another in various ways.

16. All living things carry on the same necessary life processes, such as nutrition, respiration, excretion, sensitivity, and movement.

17. The work of chlorophyll is essential to all living things.

18. Reproduction is essential if life is to continue on the earth.

19. Changes in physical surroundings are accompanied by changes in living things.

20. The more highly specialized an organism is, the more likely it is to become extinct if its environment changes.

21. The environment acts on living things, and living things act on their environment.

22. The cell is the unit of structure and function of all organisms.

23. All plants and animals are engaged in a constant struggle for energy.

24. Protective adaptations are an aid to survival.

25. The plants and animals of a given locality tend to establish a balance of nature.

26. The forms of all green plants are adapted for carrying on photosynthesis.

27. Division of labor takes place in complex organisms.

28. The less the amount of parental care, the greater is the need for the animal to be prolific.

29. To carry on better the functions of higher organisms, cells are organized into tissues, tissues into organs, and organs into systems.

30. When the environment changes, an animal must adjust itself to the change or migrate or become extinct.

31. The greater the number of similar parts in an organism, the more simple and primitive is the organism.

32. A reaction is successful if, directly or indirectly, it aids an animal to survive.

33. New living things come only from living things.

34. Nature is wasteful of life.

35. In nature, only the fittest survive.

36. Those organisms are most likely to survive and reproduce that have structures best fitted to their environments.

37. Acquired characters are not transmitted.

38. Things now living have developed from earlier living things.

39. All living things die, but life continues from age to age.

40. Many organisms survive because they are able to build artificial shelters.

Rittase

Gardening is a biological study as well as a fascinating hobby. What gardening hobbies beside those shown here can you name?

BIOLOGY FOR LEISURE TIME

The preceding eight units of this book have presented the materials necessary to give a knowledge of the nature of biology, its facts, its laws and principles, its importance and values. You may now have gained a biological background which you can use in studying and understanding life wherever you find it. It is worth while now to give more attention to the question of how to use your biological knowledge for further pleasure and for recreation.

This section describes a large number of biological pastimes, hobbies, and recreational activities. It is not intended to be studied as you have studied the preceding ones. It is intended to serve as a source to which you may turn often for ideas and directions for making the most of leisure hours. These activities described are similar in nature to the experiments, projects, and activities scattered throughout the first eight units. Those, however, were mostly intended to be carried on in school, either in the classroom and the laboratory or in the science club. The activities described here are intended to serve for recreation during the out-of-school hours both out of doors and indoors.

Biology for Leisure Time[1]

PART I. BIOLOGICAL ACTIVITIES OUT OF DOORS

Field trips and things to do. Field trips may be for the purpose of observing and identifying plants and animals or of collecting. Suppose you are going out for the purpose of observing insects. Do not rush along, or you will miss the most interesting and worth-while sights. Stop for half an hour beside an ant hill. What do you discover about ants that you never knew before? Look in the sand a few feet away from the ant hill for a cone-shaped hollow an inch or more across. Something moves at the bottom. An ant, hurrying along, suddenly finds itself sliding down the steep slopes of the hollow. It tries wildly to scramble out, but the loose sand lets it slip farther and farther down. Quickly a pair of jaws reach up from the bottom of the pit and seize the struggling ant. Thus you are introduced to the ant-lion larva, or doodle bug, the builder of the pitted trap. Use a stick to take the doodle bug out of its home. Place it on the sand and watch it build another trap.

When you go out on a trip to identify plants, take along a book which contains a key and perhaps pictures and descriptions to help you to identify the various kinds you find. Try to learn how to name and recognize common weeds, trees, and spring, summer, and autumn flowers. Even during the winter you can study the conifers and the seed pods of many flowering plants.

Field trips may be useful at any season of the year. People are likely to think that there is nothing to interest the biologist out of doors in the winter. But if you take a field trip on any mild winter day, you will be surprised at the evidences of life you can find. Have you ever tried examining the tracks in the snow to see what animals have gone before you? Can you recognize such common tracks as those of the crow, the rabbit, or the meadow mouse?

Try making plaster casts of bird and animal tracks found in moist sand or mud. You should not mix the plaster until you are ready to use it. Pour plaster of Paris into a little water and stir it with a stick or a spoon. Make the mixture thin enough so that it will pour readily. Pour it into the track, and leave it until it is well set. Remove the cast by digging carefully around it. When it is very hard and dry, you can scrape off the mud and wash the cast clean.

Look for examples of special adaptations to the environment, such as protective coloration, types of leaves suitable to the amount of sunshine, tall or flat plants, and so on. Also, look for examples of unsuccessful struggles for existence. Try to find out in each case why the struggle was unsuccessful. A dead tree in a dense thicket would furnish an example of unsuccessful struggle. Look for examples of successful struggles under difficult conditions, for example, a sturdy robin with a broken leg.

Keep a diary in which you record your outdoor observations and adventures.

Photography. It is not necessary to have an expensive camera to get good nature pictures. An ordinary small camera will give surprisingly good results if proper care is used. If your first pictures are not very satisfactory and if you have not been able

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[1] None of the activities on this and the following pages is intended as work to be assigned. All are intended to be purely voluntary and recreational.

Off for a nature trip. What equipment would they need for insect-collecting?[1]

to find where you made mistakes in taking them, ask a photographer to make suggestions of ways in which you may succeed in getting good pictures.

Try pictures of plants first. They will not run away just as you get them in focus, nor move just as you snap the shutter, though the wind may move the leaves and twigs. Such pictures as the following may be very beautiful if you will take time to get them right: (1) trees in winter outlined against the sky; (2) trees in full leaf to show typical shape and branching; (3) trees or bushes loaded with snow or sleet; (4) flowers, especially if you take these at the shortest possible distance which will give a clear picture.

Animals are often hard to photograph with an ordinary camera under usual conditions. You may with luck get close enough to a deer or other large animal to get

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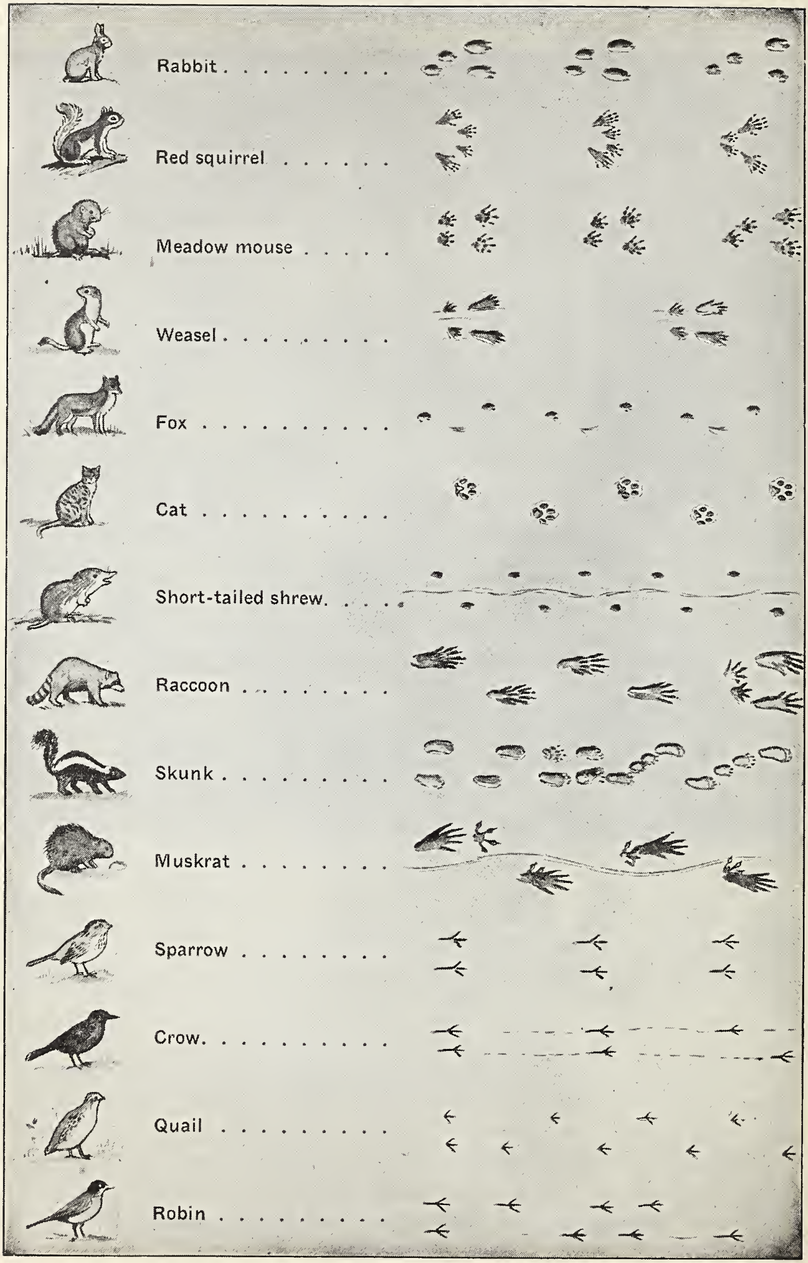
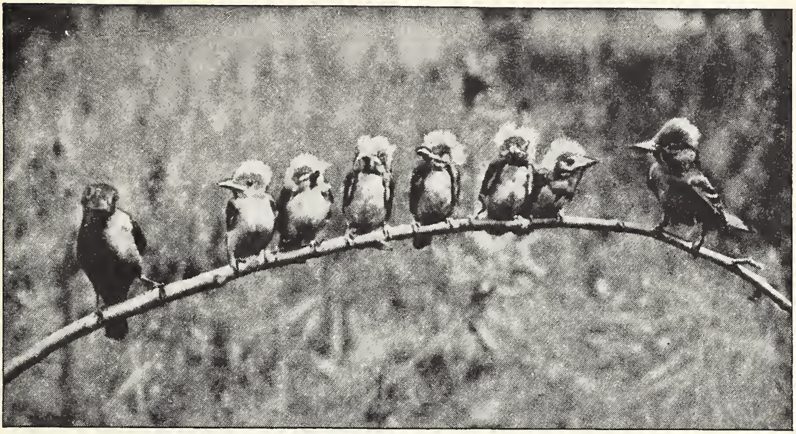
[1] **Courtesy, Girl Scouts, Inc., and *Health and Physical Education.***



Animal tracks. How do you account for the differences in these various footprints?



A family portrait. The young flycatchers were carefully lifted from the nest to the twig, where they were joined by the mother and father birds. After the picture had been taken, the young birds were carefully returned to the nest.[1] To what birds are the flycatchers related? (See page 651)

a good picture. You can climb into trees for pictures of nests and of young birds. But as a rule, you cannot get close enough to photograph a bird or a small animal with an ordinary lens. For such pictures a special lens attachment for distance is needed.

In some of the nature books or in magazines such as *Nature Magazine* look for articles describing how animals can be made to take their own pictures. Sometimes a wire across the path is adjusted so that when the animal touches the wire a flashlight explodes and the camera shutter clicks at the same instant. Sometimes the string or the wire that takes the picture is attached to food. Perhaps you can persuade the animals to pose for you by providing food or by some other means.

Bird studies. 1. *Field work.* One of the most interesting field trips is the "bird hike." The best time to go is in the early morning, just about sunrise; for then the birds will be busily hunting their breakfast. During the warmer part of the day they are usually more quiet and in the shade. If you cannot go in the morning, the early evening is a fairly good time for observations.

Take along a small notebook for keeping records, also a bird guide (see book list, p. 651), that is, a book which gives descriptions and pictures of birds. A pair of field glasses will be of help in observing the birds, but is not absolutely necessary. You can soon learn to identify many birds by their plumage. It is interesting to note, too, that you can often distinguish a bird by its manner of flight. The goldfinch, for example, flies in a peculiar series of rolling darts. The quail moves its wings rapidly

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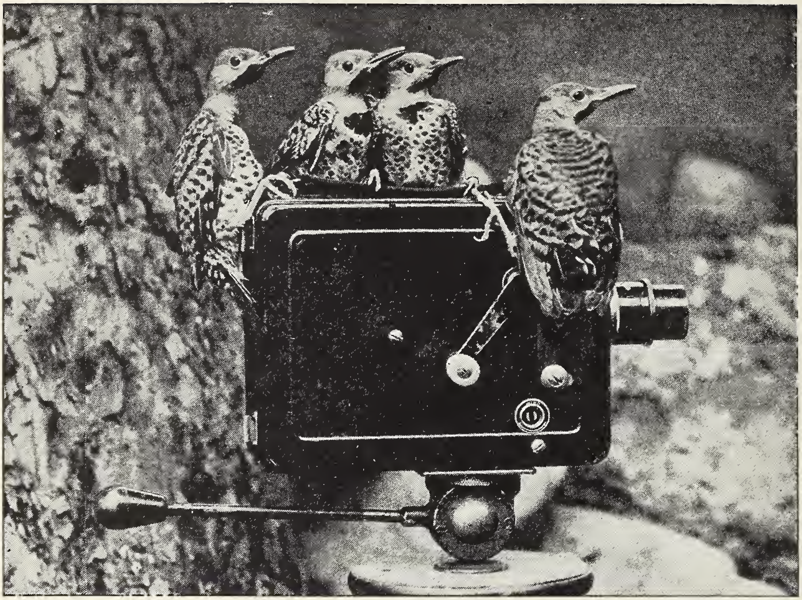
[1] From a photograph by H. T. Middleton. Courtesy of *Nature Magazine.*



Lynwood M. Chace

Hunting young flickers with a camera. "They watched me with greatest curiosity and stared with wide-open eyes at my maneuvers." Where are these birds likely to be found?

for a few beats, then glides. The robin moves its wings almost continuously. Record your observations under such headings as these: size, color, markings, habitat, season when observed, kind of food, location of nest, and the like.

Since one can often hear a bird when it cannot be seen, it is most desirable to learn some of the songs and calls. The easiest and surest way to do this is to go out with someone who knows bird-calls. You can learn much by yourself, however, by following a sound until you see the bird and by then memorizing the notes or by making a record of them in your field book.

If you would see and hear birds, be quiet in the woods. It is better to go on bird trips in very small groups. There will then be less talking and disturbance. Sit quietly in one spot for a while. Many birds which you otherwise might never see will come close to you.

It is always with a thrill that one sees the first robin or the first bluebird of the season. Many people like to make a bird calendar on which they record the dates on which each kind of bird was first observed during the year.

We rarely suspect how many kinds of birds remain with us during the winter until we start feeding them. Scatter bread, wheat, ground corn, pieces of fat meat, and other kinds of food on the ground, or tie food to the trees, or place it in boxes in the trees. Keep a record of the birds which come for food. Do the same ones come day after day? Are there some kinds that seem easily frightened away? If so, can you devise other methods of feeding them?

If there is some one in your school or neighborhood who is conducting bird-banding experiments for the Biological Survey, you may secure permission to help. You will have to devise a trap in connection with your feeding station, but of course you will have to make sure not to injure or scare the birds. It is most interesting to keep a record of the number of times the same banded bird will go into the trap. It is thrilling to discover in your trap a bird which was banded the previous year and which after its long migration has come back to the same yard.

2. *Bird houses.* Forty-five species of birds are known to nest in bird houses. But of course just any kind of house will not do. You have to put up the kind that will be attractive to the species of bird you want. You can secure from the United States Department of Agriculture a valuable bulletin giving directions for making bird houses of many kinds. If you build your bird house in the autumn, and put it out to weather through the winter, the birds will like it better than they will a very new one.

3. *Observation of nesting habits.* One of the most valuable studies is to make a detailed observation of the nesting habits of a pair of birds. You must make your study in such a way that the birds are not disturbed or frightened away. A good rule is to be quiet and make no quick or disturbing movements. Secure as much information as you can on as many of the following points as possible:

a. The building of the nest. What kind of location is chosen? What kinds of material are used? How long does it take the birds to build the nest? Do both birds work at it?

b. The eggs. How soon after the nest is completed is the first egg laid? Record in your notes the dates on which other eggs are laid. Describe the eggs as to size, color, and markings. How many eggs are laid? Does the female start incubating as soon as the first egg is laid, or does she wait until all have been laid? Does the male sit on the nest part of the time? How long at a time are the eggs left uncovered while both parents are hunting food? How many times a day? At what hours?

c. The young. How many days are required for incubation? Do all the young hatch on the same day? What is their appearance? Keep careful notes on their development. How fast do they grow? When do the feathers begin to appear? What do the parents feed the young? How do they feed them? How often? Do both parents help in getting food? How old are the young birds when they first seem afraid of you? When are the young ready to leave the nest? Describe their actions as they are learning to fly and to get food for themselves.

Your record may be illustrated by photographs. It is easy to get close enough to the nest and the young to get good pictures even with a small camera. Be very sure not to disturb the nest or to frighten the parent birds. Otherwise they may abandon the nest and the young.

Making collections. Most young people and many older ones enjoy hunting for and collecting things. You can make many kinds of collections of biological materials which will be both valuable and interesting. Here are a few suggestions. You will find others in other parts of this chapter. You will think of still others which do not appear in this book.

Sometimes one goes out on a collecting trip with the particular purpose of looking for one kind of plant or animal. But on many trips one can, if one is prepared, secure an unusual specimen which otherwise one might miss. It is well, therefore, to put into your pocket some kind of container that will protect your material until you get home. Such equipment might include some folded newspapers or paper sacks for plants, one or two bottles for live material, or an insect-killing bottle. You will thus be able to collect many different kinds of interesting specimens you would otherwise be unable to keep.

A biological collection is not merely a pile of material. It is a group of objects which bear some sort of relationship. Thus you may make a collection of living materials for an aquarium or a collection of tree leaves or of insects. Or you may select some smaller and definite part of one of the larger groups, as a collection of butterflies or of oak leaves. Another collection may relate to habitat or to habits rather than kind, as a collection of the life found in a pond, or of the insects that feed on shade trees, or of the seeds that are carried by the wind. Still another collection may contain only one species of plant or animal, as a collection of the stages in the life history of a butterfly.

The suggestions which follow are intended to help you to collect and to care for your material most effectively.

1. *Pond life.* From a pond or small lake you can collect many interesting water forms which will live well in an aquarium. You can secure many of them with your hands or by dipping with a pan or jar. For others you will need some sort of net or a wire strainer. Quart fruit jars make good collecting bottles. Do not put too many animals into one jar. You should find snails, crayfish, and perhaps mussels in the water. Along the shore you may find frogs, toads, or salamanders. Insects will probably be abundant. Water boatmen, water striders, diving beetles, water scorpions, and back swimmers are among the common ones likely to be on the surface. Then look on the bottom for the larvae of dragon flies, May flies, midges, and caddis worms.

When you return to the laboratory, put the animals in an aquarium where they will have room enough. Be sure to have water plants where some of the smaller animals can hide from their enemies. Watch the aquarium closely for a while to see which ones seem inclined to eat everything else. These you may have to put in some other place. Put a screen over the aquarium, so that the insects which live on the surface will not jump or fly out.

Many kinds of water animals will live together in an aquarium. They require little care and make interesting pets. If you do not have a regular aquarium tank, use any sort of container that seems suitable. It should be wider than it is deep, to expose a large surface to the air. Square glass battery jars make good small aquaria.

Rittase. Blair Academy, Blairstown, New York

Collecting water life. What kinds of animals should you expect to find in such a habitat? **Exercise on Scientific Method:** Which of the elements of scientific method are these boys employing here?

It is best to fill the aquarium with water from a pond or a stream. If you have to use water from the city water supply, let the tank stand for three or four days after filling it, before you put in any plants or animals. On the bottom of the aquarium put an inch of sand which has been cleaned by thorough washing to remove all dirt. Then plant the water plants. Until they get well rooted, it is well to tie a stone to the bottom of the plant to weight it down. Do not use too many plants. If you can collect the plants yourself, go to any pond or small lake or to a quiet bend in a stream and choose some of the smaller plants which grow there. A little experimenting with different kinds will tell you which grow best and look best in your aquarium. If you buy plants from a florist, get one bunch each of such plants as *Vallisneria*, *Elodea*, and *Myriophyllum*, or perhaps *Cabomba* or *Ludwigia*, or others he may suggest. Let the aquarium stand for one or two days before you put any animals into it. This gives the plants a chance to start growing and gives you an opportunity to make any changes that seem best.

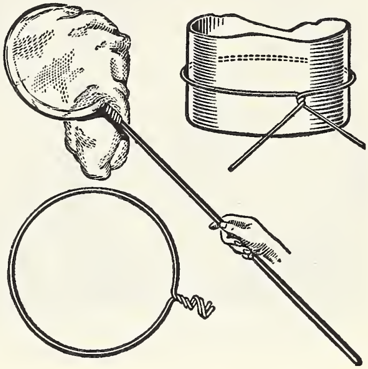
Do not crowd the aquarium. One three-inch fish to each gallon of water is enough. There is a large variety of fish to choose from: goldfish or tropical fishes; or, if you can collect them yourself, minnows, bluegills, or others of our native fishes. Put in some animals which will help to keep the aquarium clean, such as snails, tadpoles, and a clam or a mussel.

An aquarium should not stand in bright sunlight for many hours at a time. It should, however, be placed where there is plenty of room light. At times algae may grow on the sides of the tank or in the water in such abundance that one cannot see through the water. These algae do no harm, but they affect the beauty of the aquarium. Usually one can scrape the glass clean with a razor blade without removing the animals or the water from the tank.

2. *Cocoons.* After the leaves have fallen, one can usually find many cocoons. Collect as many different kinds as you can. Put them in a cool place for the winter, or keep them out of doors. If you want the moths to come out very early, you may keep them inside the home or the schoolroom. In that case do not let the cocoons become too dry. Put a moist sponge in the box with them, but do not allow it to touch them. In February or March put them in an insect cage, so that the moths will not escape when they emerge. If you have never watched a moth emerge from its cocoon and spread and dry its wings, you have a thrill to look forward to. Those which come out so early had best be added to your collection, for they could not find food outside. Directions for killing and mounting them are given in another part of this section. Do not destroy the cocoon from which the moth emerged, but mount it with the moth.

3. *Insects.* Insects may be found almost anywhere in such great numbers and of so many species that collecting them is always interesting. You will need a net to secure most of them. You will also need some sort of killing bottle. Make the net by bending a stiff wire to form a circle about twelve inches in diameter. Fasten it to a broom handle or other stiff pole at least three feet long. To the wire attach a deep bag made of mosquito netting or marquisette or any material that is light

yet strong enough so that the insects cannot push out through the meshes. For a killing bottle use any wide-mouthed jar with a tight cover. A mayonnaise jar or peanut-butter jar is quite satisfactory. Put in the bottom of the jar a piece of cotton soaked in gasoline, chloroform, carbon tetrachloride, or cleaning fluid. Over it put paper which will keep the insects from becoming wet. Do not, however, pack the paper so tightly that the fumes cannot come up into the jar. [**Caution.** *Do not yourself inhale any of these fumes.*] Fill the upper part of the jar loosely with torn strips of paper, to keep the insects from packing together and to absorb moisture that would ruin some of the specimens. Keep a separate jar for butterflies and moths. Indeed, large specimens of these insects should not be put into a jar at all. When you have one in your net, hold the net so that the insect will go into one corner. Then grasp the wings gently between thumb and finger and pour on the thorax and abdomen a little gasoline or other killing fluid from a small bottle or an oil can. When the insect is dead, place it carefully in a piece of paper folded to make an envelope. Cut in the cover of a cardboard box a slit a little larger than the size of the insect's body. With your fingers or with fine forceps carefully spread the wings fully on both sides. Place a narrow strip of paper across the wings on each side and parallel with the body. Pin the paper firmly to the cardboard, placing the pins near but not through the wings. After three days your specimen will be ready for permanent mounting.

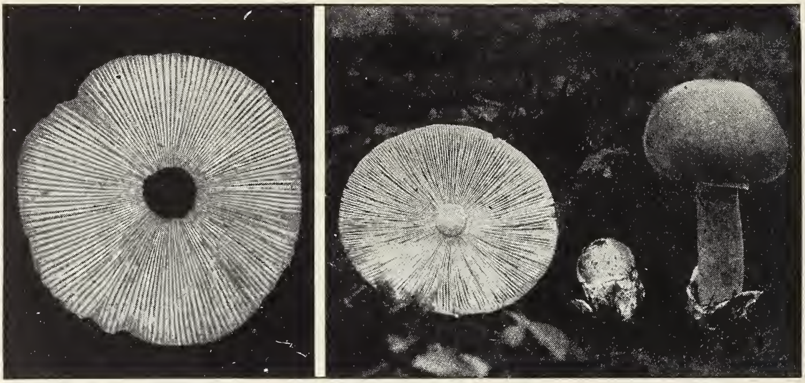


How to make an insect net. What other equipment would be necessary for insect-collecting?

A cigar box or other box which will close tightly makes a good container in which to keep the insects permanently. In the bottom put a piece of linoleum, cork board, or corrugated paper into which to stick the pins. Use either common pins or insect pins. Stick the pins through the thorax of most insects. Make small labels giving the name of the insect, the date and place where it was collected, and any other essential information. Place these labels on the pin below the insect.

Butterflies and other insects with large wings are likely to be ruined if pinned in a box with other specimens. Secure a shallow box of any dimensions which seem suitable to the number of insects you wish to mount together. Cut a piece of cotton batting to fit the box. On this place the insects, with the proper labels. Make a cover by putting a piece of glass or cellophane in the lid of the box.

4. *Tree leaves.* Most of our common trees may be readily identified by their leaves. Take an old magazine along when you go leaf-collecting. As you put a plant leaf between two leaves of the magazine, write on the margin any items which



The spore print (left) was made from this mushroom (*Amanita*). Is this mushroom edible? (Consult a mushroom book.)

will help you to identify the tree, as height, size, shape, appearance of the bark, kind of fruit. When you get home, put the leaves between newspapers. Place weights, as bricks, irons, or books, on the pile, and leave it for days until the leaves have dried.

There are many attractive ways in which you can mount the leaves. A separate sheet for each leaf is perhaps easiest to handle and to keep. Use firm enough paper so that the leaves will not readily tear off if the paper bends. Fasten the leaves with small strips of gummed paper placed over the stem and the tip of the leaf, or glue the leaf to the paper.

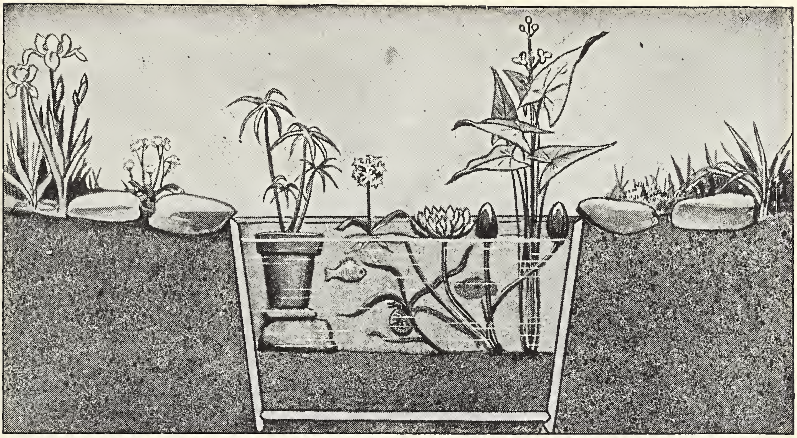
5. *Weeds.* Collect and dry whole plants in the same way as that described above for leaves. Many weeds are so large that it is not practical to use the whole plant. In that case take a portion of the stem and leaves that seems representative of the plant. When the part is dry, mount it with small strips of gummed paper, or cover it with cellophane.

6. *Flowers.* Do not pick flowers which are rare or which occur only three or four in a place. You can learn to recognize them as they grow, without helping to decrease their numbers. You might try taking pictures of them.

Collect and press flowers in the same way as leaves. If you press the flowers between sheets of waxed paper, they will keep their natural colors better.

7. *Seeds.* Make collections of weed seeds (*a*) that are carried by the wind or (*b*) that have hooks and spines which attach them to animals. Can you think of other interesting types of seed collections you might make?

8. *Fungi.* Fungi, such as mushrooms and bracket fungi, are found most readily in the spring or the autumn. The woody forms will dry and keep very well. But the fleshy-cap mushrooms are difficult to preserve. Put some of them in 70 per cent alcohol or 2 per cent Formalin solution. Very interesting spore prints can be made of many of the cap forms. Cut off the ripe cap and lay it on a piece of white paper.



A tub garden. The water garden should have a few animals—two or three fish, some snails, and perhaps a few tadpoles. Why?

Cover it with a glass or bowl to keep out air currents. Let it stand for a day until the spores have been shed. When you remove the cap, you will have a spore print showing clearly both the arrangement of the gills on which the spores were borne and the color of the spores. If you want to make your spore print permanent, coat it lightly with clear shellac.

9. *Galls.* Galls are found on cedars, willows, oaks, roses, goldenrod, blackberry, and many other plants. The gall is a growth of plant tissue usually resulting when an insect lays its eggs within the plant or when fungi grow within it. Galls may be made by tiny wasps of several kinds, by certain flies, by beetles, or by plant lice. Occasionally they are caused by roundworms. An interesting collection may be made of all the kinds you can find. Classify them according to shape and general appearance.

10. *Twigs and buds.* These are especially suitable for winter collection. After a little practice you can identify trees by the character of their buds and twigs. Dip the twigs in shellac or in wax to keep them from drying out. Then mount them on a heavy piece of cardboard or on wood.

PART II. BIOLOGICAL ACTIVITIES INDOORS

A scrapbook. A scrapbook will enable you to collect all sorts of interesting and up-to-date material to use in connection with your biology class or for a biology club. Plan to make the scrapbook rather large, perhaps nine inches by twelve inches or even twice that size. It will accommodate better the pictures you are likely to find in Sunday papers or in magazines. The rotogravure section is usually a source for fine pictures. Old magazines may contain pictures or articles of worth. Watch newspaper columns for such items as recent discoveries in disease prevention or in other fields of biology, biographical notes on living scientists, descriptions of habits of plants and animals, and similar interesting material that is not to be found in books. You may include in your scrapbook original drawings or sketches, cartoons, posters, or stories dealing with biology.

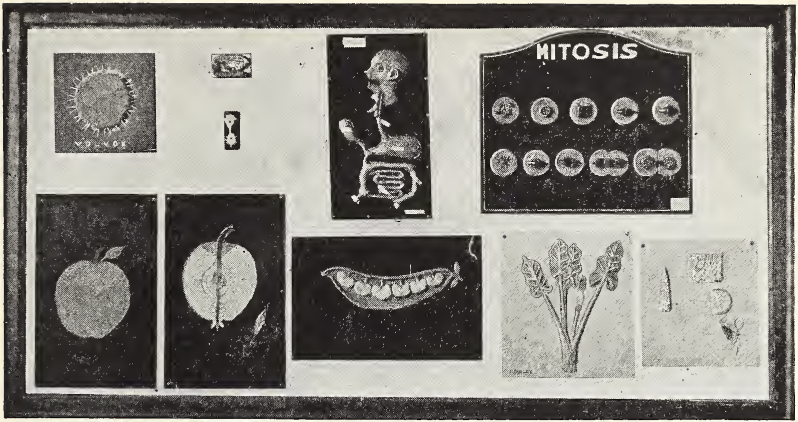
Posters or charts. Posters or wall charts make excellent exhibits to have in the classroom. They also form a valuable background for talks before the class or the science club. A few suggestions will enable you to make such posters and charts:

1. Make a poster illustrating all the animal groups. You will probably have to make the sketches free-hand because it will be difficult to find pictures of protozoans, coelenterates, and such animals in newspapers or magazines.
2. On a map of the world, paste or draw pictures of the animals characteristic of certain regions. For example, put a buffalo on central North America, a lion on Africa, and a polar bear on Alaska.
3. Make a chart which will tell partly in pictures and partly in words the "Story of Coffee," for example, from the time the coffee plant first starts to grow until the coffee reaches your table. Almost any of the articles in everyday use will make good stories, as rubber, cork, cotton, wheat, silk, wool, or leather.
4. Make a chart which will show the life history of some animal, as the cabbage butterfly. Show the sort of environment in which each stage is spent.

There are many organizations which have pamphlets, bulletins, or other publications which may contain valuable material for a scrapbook. Some of these materials are sent without charge; for other material a small price is asked. The Superintendent of Documents, Washington, D.C., will send you, on request, price lists of the various bulletins published by the departments of the Federal government. Ask for lists of publications on "Fish," "Birds," "Forests," or any other subject in which you are interested. From the Bureau of Biological Survey you can obtain lists of birds, information on bird-banding, and much other material related to bird habits. The United States Forest Service has a wealth of material you may have for the asking. It also has photographs which are sold to you at cost. Valuable national-parks pamphlets may be secured from the Bureau of National Parks, Department of the Interior, Washington, D. C., and from the Department of the Interior, Ottawa, Ontario.

Many motion pictures will be lent to your school at no cost except that of transportation. Write to the United States Department of Agriculture for a list of the subjects included.

You can secure much information from various state departments. The state Fish and Game Commission will answer questions regarding hunting laws, wildlife distribution, and problems of conservation. The state division of the Forest Service can give help on problems which relate to forestry and forest life. The



Alfred F. Nixon

Models made by high-school students. Can you suggest other good subjects?

various departments of your state university or other college or university will always co-operate by answering questions and giving advice.

The American Nature Association, Washington, D. C., the National Wild Flower Preservation Society, Washington, D.C., and the National Association of Audubon Societies, New York City, are other sources of information.

If you like to draw. If you have ability to draw and if you enjoy drawing, try to make some large permanent wall charts for the biology laboratory or for your room at home. These may be either original sketches or copies of drawings in a textbook. Some which might be very useful are (1) grasshopper, (2) flower parts, (3) cross section of leaf, (4) life cycle of the tapeworm.

Charcoal or pencil sketches of trees in winter give good results even for the beginning artist. The bare branches against the sky show so well the habits of the tree that such a sketch is often a very satisfactory identification.

Cartoons not only are amusing, but help to illustrate a point in a way that is remembered. Try to make cartoons based upon such problems as conservation, forest-fire prevention, bird protection, conservation of wild flowers, the fight against insects, or the struggle for existence.

Making models. Perhaps you have seen in your laboratory or in a museum models of plants or animals or of some of their parts. You can use Plasticine or modeling clay to make excellent models. For example, try to make a model which will show the parts of a flower. You may use pieces of wood or wire to stiffen such parts as stem, pistil, and stamens. When all parts are put together to make the complete flower, support the model in a box or between blocks of wood until dry. Then paint the parts different colors.

Model formal garden. The watch shows the sizes of objects in the garden. **Project 28:** Construct soap carvings similar to these to be used in another such model garden

Another kind of model might be that of the inside of a leaf. Use the top of a box (for example, a shallow shoe box) as a support for your model until it dries. Make the separate cells by rolling and molding the clay to proper shape. Assemble them to look like the figure on page 80. You may color this model to make it more natural and attractive.

It is not difficult to make a good model of a protozoan such as a paramecium.

You can make good modeling material out of old newspapers. Soak them in water until they are soft. Then make a smooth pulp by rubbing the paper between the hands and forcing it through a sieve or screen.

Recreation with the microscope or hand lens. When you are collecting along a river or pond, bring in a small jar of mud from the bottom. Put the mud into a flat dish with water, and cover it. Let it stand a day or so. Then examine the water with a lens, or make slides and examine them with the low power of the microscope. How many kinds of animals do you find? If you consult a textbook or a reference book on fresh-water biology, you may be able to identify them as protozoans, roundworms, earthworms, rotifers, and the like. But you will not be able to find exact names for every kind of animal. Do not expect your teacher to know what all these animals are. No teacher could know the thousands of possible kinds of animals you may find. The animals are fascinating to watch, even if it is impossible to name them all. Keep a record either in notes or in sketches of the interesting things you observe, as what and how the animal eats, how it moves around, and how it fights its enemies.

Keep this aquarium for a month or more, and examine it occasionally. You will be surprised at the changes in animal life that take place. Animals that were abundant at one time may disappear, and others that you did not know were in the aquarium will become most numerous.

Making an indoor garden. 1. Plant bulbs in a shallow dish filled with small rocks and coarse gravel, and fill the dish with water. Some of the best bulbs for this purpose are paper-white narcissus, hyacinth, and calla lily.

2. Many kinds of plants will grow from cuttings, or slips. In the fall, before frost comes, look around for plants which can furnish material for the school greenhouse. Geraniums, begonias, wandering Jew, and foliage plants (*Coleus*) are among the plants which grow readily from slips. Cut off the top of a branch, remove larger leaves, and place the slips in sand until they root. Then transplant them to flowerpots, window boxes, or hanging gardens.

3. Perhaps you have seen in a florist's window a large glass bowl or jar that contained a miniature garden. You can make a similar one easily. Use a bowl with flat sides by preference, such as a goldfish bowl. In the bottom put moist soil, sand, or peat moss. Then plant any small plants the tops of which do not come above the top of the bowl. Do not put in too many. Many small weeds are really beautiful. Moss used to carpet the surface adds much to the beauty of the garden. Put a piece of glass over the top of the bowl to prevent evaporation of water. This garden makes an attractive table centerpiece or a gift for a sickroom.

Terraria. Many interesting groups of plants and animals can be kept in the laboratory or at home. Bring in turtles, salamanders, toads, frogs, snakes, or lizards. Keep them in a cage where their environment is as natural as it is possible to make it. Use an aquarium or similar container or make a terrarium as follows: Secure a shallow wooden box about eighteen by twenty-four inches. Against each side, on the inside of the box, stand pieces of glass cut to fit into the box and about twelve inches high. Put in soil to the level of the top of the box. This soil will hold the glass in place at the bottom. To keep it from bulging, run a strip of tape around the outside of the glass pieces near the top. Make a glass cover to fit. You will of course have to vary the dimensions to suit the size of the living things you are going to keep.

A moist woodland terrarium should contain moss, small ferns, toads, salamanders, small wood tortoises, snails, and any other forms of life characteristic of the woods. Keep the terrarium covered to prevent evaporation. If the animals are fed enough food, they should live through the winter in good condition. Occasionally take the cover off to permit airing out.

A bog terrarium may contain pitcher plants, sundew, dwarf cranberry, moss, frogs, salamanders, and other animals that you find in very moist places. Remember that bog plants require acid soil. Therefore it is best to use only the soil in which you find the plants growing.

In very early spring bring pieces of soil in from the woods. Put them in a terrarium, water them well, and cover the terrarium to prevent too rapid evaporation of water. You will be surprised at the numbers of plants and animals that will appear.

Food for animal pets. The problem of obtaining food during the winter months for the lizards, frogs, and turtles that are kept in captivity is often difficult. Here are directions for raising three types of food animals that are easily reared in large numbers:

The cockroach. Secure a pair of cockroaches, or a female carrying an egg case. Put them in a gallon battery jar or other wide-mouthed jar. In the bottom of the jar place a layer of sawdust. Cover the jar with a tightly fitting lid in which there are tiny holes to admit air, or tie a piece of cheesecloth over the top. A ring of vaseline just inside the jar will discourage attempts of the insects to crawl out. Put the jar in a warm dark place.

These insects will eat almost anything, though you will probably find that they prefer some foods to others. Try them with bread soaked in water, with some lettuce or cabbage. Keep a dish of water in the jar at all times.

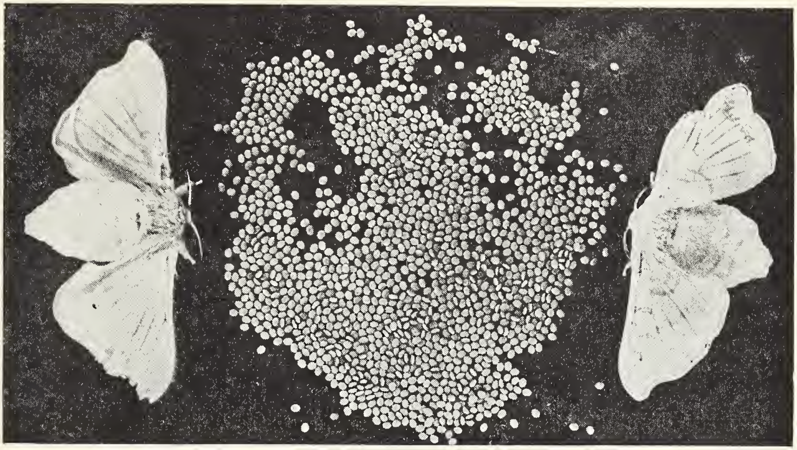
The female cockroach will carry the egg case around with her until the young are ready to hatch. Then she will hide it somewhere in the sawdust. The young will emerge by the next morning. Use care to see that none of the insects escape, because they are filthy pests in the house and once established are extremely difficult to eliminate. If the lizards or turtles do not eat the cockroach at once, it is better to remove the insect from the cage. Otherwise it will hide and may later escape into the building.

Mealworms. Such foods as oatmeal, flour, and corn meal sometimes become wormy. These "worms" are the larvae of a beetle. They are excellent food for fish, frogs, and salamanders. Put some of the worms in a jar over which you tie a cloth. They will form a pupa, hatch, and lay eggs. You can soon have several jars in which the worms are in various stages of development, thus ensuring a steady and plentiful supply of fish food.

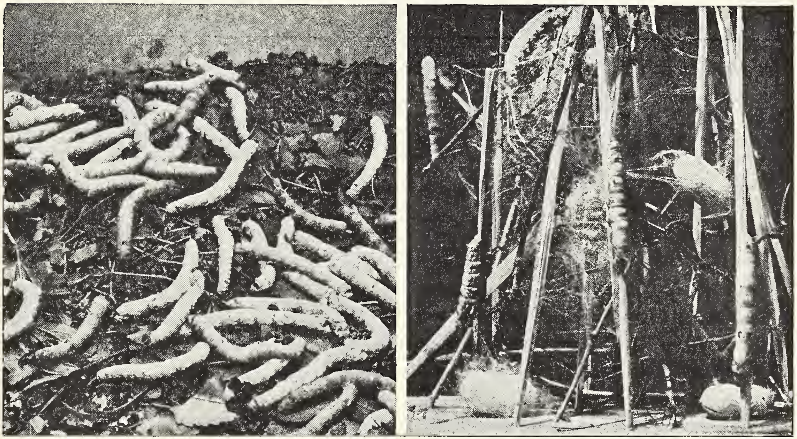
Earthworms. Many of the smaller earthworms can be kept all winter in the laboratory with very little work. Secure a large wooden box about six inches deep. Bore a few holes in the bottom for drainage. First put in a layer of sand or gravel, and then fill the box with rich soil. Keep the soil moist but not wet. If the worms are dropped on top of the soil, they will soon burrow in. One can keep a great number of worms in one box if they are supplied with plenty of food. Among the foods they like best are pieces of lettuce and cabbage leaves. Do not be worried if the worms seem to pay no attention to the leaves until these are somewhat decayed. They like decayed leaves best.

Keeping insects in the classroom. In addition to the animals suggested in other parts of this chapter as suitable for keeping in the classroom, many insects are interesting to keep and observe.

Silkworms are very easy to raise and are intensely interesting to watch. The commercial silkworm differs from our native cocoon-spinning moths in that it passes the winter in the egg stage rather than in a cocoon. As long as the eggs are



Adults and eggs



Cornelia Clarke

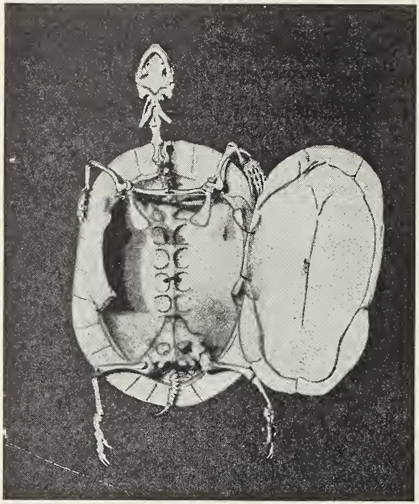
Larvae

Larvae and Cocoons

Silkworms. In what sense is the silkworm a domesticated animal? Can you explain the life cycle of the silkworm from these pictures? If another picture were added below these to show the next stage in the life cycle, what stage would it present?

kept cool, they will not hatch. You must take advantage of this fact in planning your activities, for you do not want the worms to hatch before there are leaves to feed upon. The silkworm thrives best on the leaves of the mulberry, though it can be raised on Osage-orange leaves or dandelion leaves.

Order the eggs from a biological supply house in February or March, and keep them in a cool place or in the ice box until the mulberry leaves are almost out. The eggs will hatch in a week or ten days after they are brought into a warm room. Put them in a shoe box or similar container when you bring them into the room. As soon as the first caterpillars appear, put two or three fairly large mulberry leaves into the box. They will not thrive on the small new leaves. It is well, too, to see that the leaves are not wet. If you keep a few fresh leaves in the box at all times, the caterpillars will not crawl away. It is therefore not necessary to cover the box. As the worms get larger, they will eat astonishingly large quantities of food. They feed for about a month before attaining their full growth. At that time they are ready to spin their cocoons. They become restless, eat very little, and will now wander away from the box. To prevent their straying, put into the box some twigs to which they can fasten the cocoons.


M. E. Van Ells

This turtle skeleton was prepared and mounted by a high-school pupil in the manner here described. What values might one derive from preparing animal skeletons?

When the cocoons are completed, remove them to an insect cage or a box covered with mosquito net or screen. In about two weeks the adults will emerge from the cocoons. Within a few days they will mate and lay eggs. Then they will die. The adult moths never eat. The female will lay the eggs on any surface. In order to make it easier to remove the eggs, stand pieces of cardboard along the sides of the cage, or paste flaps of paper to the box where the adults are kept. To keep the eggs from hatching, put them in a cool place.

Mounting skeletons. The method here described for mounting a turtle skeleton would serve for mounting the skeleton of any small animal. Secure a medium-sized turtle and kill it with ether or in some other humane way which will not injure the skeleton. Saw through the lower shell at both sides and carefully remove the lower plate from the upper. Cut off as much flesh as possible without disturbing any of the bones. Place both plates in water which is slightly warm, and leave them there for a week or until the flesh has decayed sufficiently so that it slips easily from the bones. Carefully remove the flesh from the bones, taking care not to lose any of the bones. If you object to handling the decaying flesh with your bare hands, wear rubber gloves. As you remove the various bones, lay them together in the same

United States Department of the Interior

Feeding a chipmunk, Mount Lassen National Park, California. Do the relatives of this animal make equally good pets?

relative positions that they had in the body. Be sure that the bones are entirely clean. If you experience difficulty in removing the last bit of flesh, put the bones into an aquarium with goldfish; the fish will quickly eat the small particles of flesh without injuring the skeleton. Mount the skeleton, using collodion or transparent lacquer to cement the bones together. Attach the bottom shell plate to the upper one in its original position, using small brass hinges. Mount the entire skeleton on a block of wood with a strong wire for support. After the mounted skeleton is thoroughly dry, cover the entire surface with a coat of lacquer; this will keep the skeleton clean and will enable you to dust it easily. In dusting it, use a camel's-hair brush in place of a dusting cloth.

Keeping pets. Many wild animals make interesting pets both in captivity and in their native habitats. Most of them can be kept alive and healthy in captivity. Of course, one must learn all one can about the habits of the animal in order to provide it with a suitable home and proper food. Remember that practically all wild animals need a place in which to hide. It is most cruel to keep them in open cages where they are exposed on all sides to possible enemies. But if they are cared for properly, there should be no possible objection to keeping them. There is every probability that most kinds of animals in captivity will live longer and more comfortably than in their native state. They are protected from enemies, and are supplied with abundant food without having to hunt for it.

Snakes frequently will not eat in captivity. One must therefore set them free after a week or so. Turtles, salamanders, toads, horned toads, and other lizards make interesting pets that are not at all hard to keep.

Reading for pleasure. There are so many excellent books written about plants and animals that it is difficult to make a list which will include everyone's favorites. The brief list which follows is made up of books that many boys and girls have found most interesting. You will often find other books by the same or by other authors which you may like even better.

Akeley, C. E. *In Brightest Africa.* Doubleday, Doran & Company, Inc., New York.
Beebe, William. *The Arcturus Adventure.* G. P. Putnam's Sons, New York.
Beebe, William. *Beneath Tropic Seas.* G. P. Putnam's Sons, New York. Also $1 edition, Blue Ribbon Books, Inc., New York.
Beebe, William. *Jungle Days.* G. P. Putnam's Sons, New York. Also $1 edition, The Garden City Publishing Company, Inc., New York.
Chapman, W. G. *Green Timber Trails.* D. Appleton-Century Company, Inc., New York.
Curie, Eve. *Madame Curie.* Doubleday, Doran & Company, Inc., New York.
de Kruif, Paul. *Fight for Life.* Harcourt, Brace and Company, New York.
de Kruif, Paul. *Hunger Fighters.* Harcourt, Brace and Company, New York.
de Kruif, Paul. *Men against Death.* Harcourt, Brace and Company, New York.
de Kruif, Paul. *Microbe Hunters.* Harcourt, Brace and Company, New York.
Ditmars, R. L. *Strange Animals I Have Known.* Brewer, Warren & Putnam, New York.
Dorsey, G. A. *Why We Behave Like Human Beings.* Blue Ribbon Books, Inc., New York.
Dugmore, A. A. R. *The Romance of the Beaver.* J. B. Lippincott Company, Philadelphia.
Ellsworth, Lincoln. *Beyond Horizons.* Doubleday, Doran & Comany, Inc., New York.
Fabre, J. H. *Insect Adventures.* Dodd, Mead and Company, New York.
Fishbein, Morris. *Shattering Health Superstitions.* Liveright Publishing Corporation, New York.
Furnas, C. C. *Man, Bread and Destiny.* Reynal & Hitchcock, Inc., New York.
Furnas, C. C. *The Next Hundred Years.* Reynal & Hitchcock, Inc., New York.
Heiser, V. G. *An American Doctor's Odyssey.* W. W. Norton & Company, Inc., New York.
Hornaday, W. T. *Tales from Nature's Wonderlands.* Charles Scribner's Sons, New York.
Johnson, M. E. *Lion: African Adventures with the King of Beasts.* Blue Ribbon Books, Inc., New York.
Kallet, Arthur, and Schlink, F. J. *100,000,000 Guinea Pigs.* Grosset & Dunlap, Inc., New York.
Knight, C. R. *Before the Dawn of History.* McGraw-Hill Book Company, Inc., New York.
Lane, Janet. *Your Carriage, Madam!* Chapman & Hall, Ltd., London.
Lucas, F. A. *Animals of the Past.* American Museum of Natural History, New York.
Maeterlinck, M. *The Life of the Bee.* Dodd, Mead and Company, New York.
Mills, E. A. *The Story of a Thousand-Year Pine.* Houghton Mifflin Company, Boston.

Mills, E. A. *Watched by Wild Animals.* Doubleday, Doran & Company, Inc., New York.
Reed, W. M. *The Earth for Sam.* Harcourt, Brace and Company, New York.
Rolt-Wheeler, Francis. *The Boy with the U. S. Naturalists.* Lothrop, Lee & Shepard Company, Boston.
Rourke, Constance. *Audubon.* Harcourt, Brace and Company, New York.
Scoville, Samuel, Jr. *Everyday Adventures.* Little, Brown and Company, Boston.
Scoville, Samuel, Jr. *Wild Folk.* Little, Brown and Company, Boston.
Seton, E. T. *Wild Animals I Have Known.* Charles Scribner's Sons, New York.
Sharp, D. L. *The Face of the Fields.* Houghton Mifflin Company, Boston.
Wheeler, W. M. *Social Life among the Insects.* Harcourt, Brace and Company, New York.
Williamson, J. E. *Twenty Years under the Sea.* E. M. Hale and Company, Milwaukee.
Zinnser, Hans. *Rats, Lice and History.* Little, Brown and Company, Boston.

Among the reference books which you will find particularly useful in carrying out various projects in biology are the following.

Chapman, F. N. *Color Key to North American Birds.* D. Appleton-Century Company, Inc., New York.
Cowles, H. C., and Coulter, J. G. *Spring Flora.* American Book Company, New York.
Dickerson, M. C. *The Frog Book.* Doubleday, Doran & Company, Inc., New York.
Ditmars, R. L. *The Reptile Book.* Doubleday, Doran & Company, Inc., New York.
Forbush, E. H. *Useful Birds and Their Protection.* State Board of Agriculture, Boston.
Holland, W. J. *The Butterfly Book.* Doubleday, Doran & Company, Inc., New York.
Howard, L. O. *The Insect Book.* Doubleday, Doran & Company, Inc., New York.
Jordan, D. S., and Everman, B. W. *American Food and Game Fishes.* Doubleday, Doran & Company, Inc., New York.
Keeler, H. L. *Our Native Trees.* Charles Scribner's Sons, New York.
Locy, W. A. *Biology and Its Makers.* Henry Holt and Company, Inc., New York.
Lutz, F. E. *The Field Book of Insects.* G. P. Putnam's Sons, New York.
Mathews, F. S. *Field Book of Wild Birds and Their Music.* G. P. Putnam's Sons, New York.
Mathews, F. S. *The Book of Wild Flowers for Young People.* G. P. Putnam's Sons, New York.
Morgan, Ann. *Field Book of Ponds and Streams.* G. P. Putnam's Sons, New York.
Reed, C. A. *Bird Guide.* Doubleday, Doran & Company, Inc., New York.
Rogers, J. E. *The Tree Book.* Doubleday, Doran & Company, Inc., New York.

Writing biology dramas. The history of biology, as found in textbooks, encyclopedias, and other sources, is full of incidents which can be made into plays to be presented in the biology classroom, in the school assembly, or in the science club. Suitable subjects for such plays are "The Conquest of Yellow Fever," "Overthrowing the Theory of Spontaneous Generation," "From Witch-doctor to Modern Medicine," and the like. You will often find it difficult to secure accurate information concerning the details of the incident. You will have to invent the conversation in most of your scenes. Make your stage directions as simple as possible. Here is a sample of this kind of play, revised from a play written by Donald Smith and Stella Arthur.

THE CONQUEST OF HYDROPHOBIA

Scene I · [Time] *About fifty years ago.* [Place] Pasteur's *home in Paris.* [Characters] Frau Meister *of Alsace, France*; *her son,* Joseph; Louis Pasteur. [*As the scene opens,* Pasteur *and* Frau Meister *are seated, and* Joseph *is standing by his mother, in* Pasteur's *living room.*]

Frau Meister. We have come to you, Monsieur, because you alone in all the world can save Joseph's life. We have heard of your great work, and have hurried without stopping until we reached your house.

Pasteur. Is it the bite of a rabid dog, Madame, which has injured your son?

Frau Meister. Yes, Monsieur. My brave Joseph was bitten by a mad dog when he kept the dog from biting the smaller children. He killed the dog, Monsieur, but not until it had bitten him fourteen times. We are terribly worried. So brave a boy should not die.

Pasteur. My treatment for rabies has never been tried on any human being, but only on rabbits and dogs. I do not know whether it would cure Joseph, and I fear to try lest the treatment might not be successful.

Frau Meister. Oh, but you must, Monsieur. It is the only chance to save my Joseph's life.

Joseph. You will give me the treatment, won't you, Monsieur Pasteur? You know I shall die if you do not help me.

Pasteur. I may not have any right to try it. I fear you may die if I do.

Joseph. But that will not be your fault, Monsieur. I am willing to take that chance. I have no other chance to live.

Frau Meister. Yes, Monsieur, I will take all the responsibility for the treatment; I will take all the blame in case the treatment is not successful. We hear that the men who work with you do not want you to treat a human being yet, but we cannot wait until they are ready. Joseph will die.

Joseph. You will do it, won't you, Monsieur?

Pasteur. Yes, Joseph, I cannot refuse. I will give you the treatment. Come with me. [*Exeunt all three as the curtain falls.*]

Scene II · [Time] *Two nights later.* [Place] Pasteur's *study.* [Characters] Pasteur, *a* physician, and Madame Pasteur. [*Present and seated are* Pasteur *and a* physician.]

Physician. The boy is sleeping quietly, is he not?

Pasteur. Yes, yes. So very quietly. I fear he may be getting weaker.

Physician. You gave him exactly the same doses you gave the dogs in the laboratory, did you not?

Pasteur. You are right. At first, I gave him serum that had very weak rabies germs in it. And today I gave him a much stronger dose.

Physician. Then tomorrow you will use serum that is even stronger?

PASTEUR. Yes, that is what I do with the dogs. For fourteen days I give them the serum, increasing its strength a little each day.

PHYSICIAN. Do the dogs always get well?

PASTEUR. Almost always. I do not understand exactly why, but they do. I hope it will be the same with Joseph. I am so anxious that I can't sleep, and I can hardly think about anything else.

PHYSICIAN. I sincerely hope Joseph will get well. [*Rises and goes to the door.*] Good night, Monsieur Pasteur.

PASTEUR. Good night, Doctor.

[PASTEUR *seats himself at his study table staring straight ahead with a troubled expression. He rises and paces the floor. The door opens and* MADAME PASTEUR *appears in the doorway.*]

MADAME PASTEUR. Louis, it is so late, and you need rest and sleep so badly.

PASTEUR. I cannot sleep for worry about that boy Joseph. Suppose the treatment does not protect him, and he dies the awful death which rabies causes! It means so much if he gets well.

MADAME PASTEUR. He will not die.

PASTEUR. It is not as if I surely knew what to do. This is an experiment in which I have no choice but to use Joseph instead of a rabbit, a dog, or some other animal. Don't you see what it means?

MADAME PASTEUR. Oh yes, but you are doing your best, and better than anybody else in all the world could do.

PASTEUR. But my best may not be enough. I may fail to save the boy.

MADAME PASTEUR. You will not fail. God will not let you fail. But come now and rest. If you should yourself become ill, then nothing could save the boy.

PASTEUR. I will try to sleep soon, but I must think and plan for a while. Perhaps there is something more that I can do for Joseph, something which I have not yet thought of.

[MADAME PASTEUR *shakes her head sadly and closes the door as the curtain falls.*]

SCENE III · [Time] *Four weeks later.* [Place] PASTEUR'S *living room.* [PASTEUR, JOSEPH, *and* FRAU MEISTER *are seated.*]

PASTEUR. And how do you feel, Joseph?

JOSEPH. I am well, Monsieur, very well. The wounds made by that dog's teeth are now almost entirely healed, and I have no pain whatever.

PASTEUR. I think you are now out of danger, Joseph. There is no longer anything to fear. You are the first human being I have cured of rabies.

FRAU MEISTER. God bless you, Monsieur Pasteur. You have saved the life of my boy. We cannot thank you enough.

PASTEUR. And the way has been found to save many lives from one of the most terrible human dangers.

CURTAIN

Gendreau

GLOSSARY

The following terms are important in the study of biology. The page number or numbers given with each term indicate a page or pages on which the word is used in a way that makes its meaning readily understood. An asterisk following a page number indicates that the definition is made clear by an illustration on that page. Referring back to the pages or illustrations indicated will be of great help to you in recalling and fixing the meanings of the terms.

The terms preceded by an asterisk are those which were considered essential by at least two thirds of the 324 teachers of biology who indicated their judgments in the investigation mentioned on page iv of the Preface.

Most of the pronunciation symbols are self-explanatory. The values of the following symbols are briefly indicated: āle, ădd, ärm, ȧsk, sofȧ, ēve, ĕnd, makẽr, īce, ĭll, ōld, ôrb, ŏdd, cūbe, ûrge, ŭp, fo͞od, fo͝ot, cult͜ūre.

abdomen (ăb dō′mĕn): the part of the body including the chief digestive organs; the posterior part of the body of an insect, arachnid, or crustacean (p. 195).

*absorption (ăb sôrp′shŭn): the process of taking in a substance, as a sponge absorbs water (p. 377).

acquired immunity (ĭ mū′nĭ tĭ): state of being immune through having had a disease or having been vaccinated (p. 484).

*adaptation (ăd ăp tā′shŭn): that structure or behavior which fits an organism to live in its environment (pp. 59–60).

adenoids (ăd′ē noidz): undesirable tissue growing on the back wall of the pharynx (pp. 389* and 524).

adrenals (ăd rē′nălz): endocrine glands located on the kidneys (p. 405*).

*algae (ăl′jē): the group which includes the simplest green plants (p. 129).

alimentary (ăl ĭ mĕn′tȧ rĭ) canal: all the organs through which food passes in digestion (p. 344*).

alternation of generations: the condition in plants or animals in which the sexual and the asexual stage each produces the other, the two stages completing the life cycle (pp. 161 and 579*).

alveoli (ăl vē′ō lī): the small air sacs (baglike structures) in the lungs (p. 391*).

amoeboid (a mē′boid): like an amoeba (p. 151).

*Amphibia (ăm fĭb′ĭ ȧ), or amphibians (ăm fĭb′ĭ ănz): a group of animals all of which have gills in early life, and most of which as adults develop lungs, such as frogs, toads, and salamanders (p. 211).

anabolism (ȧ năb′ō lĭzm): all the processes by which the cells build protoplasm from food (p. 394).

anatomy (ȧ năt′ō mĭ): the study of the structures of living things (p. 5, footnote).

angiosperms (ăn′jĭ ō spûrmz): the group of flowering plants the seeds of which develop in an ovary (p. 142).

Annelida (ă nĕl′ĭ dȧ), or annelids (ăn′ĕ lĭdz): the phylum of segmented worms, which includes earthworms and sandworms (p. 173).

*annual (ăn′ū ăl): living for only one year (p. 102).

annual ring: the cylinder of tissue produced by one year's growth of a stem, such as the stem of a tree (p. 102).

antenna (ăn tĕn′ȧ): a jointed appendage which bears sense organs and which appears on the head of such animals as insects and crustaceans (p. 195).

***anterior** (ăn tēr′ĭ ẽr): toward the head (p. 176).

***anther** (ăn′thẽr): the club-like tip of the stamen, in which pollen is formed (p. 55*).

antibodies (ăn′tĭ bŏd ĭz): all the various substances which the cells manufacture as a means of combating disease germs (p. 482).

antiseptic (ăn tĭ sĕp′tĭk): a substance, such as tincture of iodine, which kills bacteria or prevents their growth (p. 132).

antitoxin (ăn tĭ tŏx′ĭn): a substance produced by the body, which counteracts the effects of toxins, or poisons, produced by germs (p. 494).

aorta (ā ôr′tȧ): the largest artery in the body, and the one that carries the blood from the left ventricle out into the body (p. 367*).

***appendage** (ă pĕn′dĭj): a structure, usually jointed, which is attached to the body, as a leg, an arm, or a tentacle (p. 191*).

***aquatic** (ȧ kwăt′ĭk): pertaining to water. An aquatic plant or animal is one that lives in the water (p. 177*).

Arachnida (ȧ răk′nĭ dȧ), or **arachnids** (ȧ răk′nĭdz): the class of arthropods to which spiders and ticks belong (p. 187).

***artery** (är′tẽr ĭ): a blood vessel leading away from the heart (p. 367*).

Arthropoda (är thrŏp′ōdȧ), or **arthropods** (är′thrō pŏdz): the phylum of animals, including insects, crustaceans, and spiders, which have exoskeletons and jointed appendages (p. 184).

asexual-spore reproduction: reproduction secured by spores that are not formed by the union of cells (p. 553*).

***assimilate** (ă sĭm′ĭ lāt): to change digested food into living protoplasm (p. 376).

assimilation (ă sĭm ĭ lā′shŭn): the process of changing digested food into living protoplasm (p. 376).

auricle (ôr′rĭ kl): a chamber of the heart which receives blood from the veins (p. 367*).

Aves (ā′vēz): the class of chordates which includes all birds (p. 225).

axillary (ăx′ĭ lẽr ĭ): in the angle, as between the base of a leaf and the stem from which the leaf grew (p. 101*).

bacillus (bȧ sĭl′ŭs), *plural* **bacilli** (bȧsĭl′ī): a bacterium of the one of the three types of bacteria which has a characteristic rod-like shape.

***bacteriology** (băk tēr ĭ ŏl′ō jĭ): the branch of science which deals with bacteria (p. 5).

***bacterium** (băk tēr′ĭ ŭm), *plural* **bacteria** (băk tēr′ĭ ȧ): one of the simplest and smallest plants; a minute, one-celled fungus plant (p. 132*).

balance of nature: a condition in which the plants and animals of a region maintain relatively unchanging numbers (p. 61).

***beetle** (bē′tl): an insect (order Coleoptera) having hard outer wings which completely cover the inner wings (p. 262*).

biennial (bī ĕn′ĭ ăl): a plant which lives for only two years, storing food the first year and producing seeds the second (p. 73).

bilateral symmetry (bī lăt′ẽr ăl sĭm′ē trĭ): a symmetry which consists in two similar halves, as the halves of the body, which completely match each other (p. 164).

***bile** (bīl): the fluid secreted by the liver, which aids in the process of digestion (p. 349).

biological (bī ō lŏj′ĭ kl) **succession:** the slow changes in the kinds of living things in a region which result from the changes in the environmental factors of the region (p. 24*).

***biologist** (bī ŏl′ō jĭst): a scientist who makes a special study of biology (p. 3).

***biology** (bī ŏl′ō jĭ): the study of both plants and animals (p. 5).

***bladder** (blăd′ẽr): a bag-like organ with walls of muscle or membrane, in which a liquid is collected (p. 349*).

***blade** (blād): the expanded, flat portion of a leaf (p. 79*).

blastula (blăs′t͜ū lȧ): a stage of development of an animal embryo in which it resembles a hollow ball (p. 577*).

***blood** (blŭd): the fluid which circulates in the bodies of many animals, carrying materials to and from the cells (p. 372).

***botany** (bŏt′ȧ nĭ): the branch of biology which deals with the study of plants (p. 5, footnote).

bronchi (brŏng′kī): the two large branches of the trachea, or windpipe, which lead to the lungs (p. 391*).

Bryophyta (brī ŏf′ĭ tȧ): the phylum of plants which includes mosses and liverworts (p. 138).

***bud:** the tip of a stem or of a branch which contains immature leaves or flowers; any many-celled growth upon a parent organism which will produce a new plant or animal (pp. 101* and 552*).

***budding** (bŭd′ĭng): a form of asexual reproduction; a method of grafting (pp. 552* and 557*).

bug: an insect (order Hemiptera) which has sucking mouth parts, and wings of which the front portion is opaque and the rear portion transparent. Examples are squash bug and stinkbug (p. 586*).

Calorie (kăl′ō rĭ): the amount of heat used in raising the temperature of one kilogram of water one degree centigrade (this is the large calorie) (p. 323).

***calyx** (kā′lĭx): the outer part of a flower, usually green; all the sepals together (p. 55*).

***cambium** (kăm′bĭ ŭm): the growing tissue between the xylem and the phloem in the vascular bundles (p. 97*).

capillarity (kăp ĭ lăr′ĭ tĭ): the rise of liquids in small tubes and spaces, as in plant cells and in soil (p. 90).

***capillary** (kăp′ĭ lẽr ĭ): a minute blood vessel which connects an artery and a vein (pp. 363* and 366*).

carapace (kăr′ȧ pās): the hard covering on the dorsal, or upper, surface of crustaceans and turtles (pp. 191 and 648*).

***carbohydrate** (kär bō hī′drāt): a food substance, including sugars and starches, which contains definite proportions of carbon, hydrogen, and oxygen (p. 85).

***carbon** (kär′bŏn): one of the chief elements composing protoplasm and the energy foods (p. 39).

***carbon dioxide:** a colorless, odorless gas composed of one part of carbon and two parts of oxygen (p. 22).

carnivorous (kär nĭv′ō rŭs): relating to the Carnivora, that is, the animals that eat the flesh of other animals (p. 234).

cartilage (kär′tĭ lĭj): a tough, elastic animal tissue; gristle (p. 207).

catabolism (kȧ tăb′ō lĭzm): the processes involved in breaking up the protoplasm of living cells (p. 394).

***cell:** one of the units of protoplasm, of which all living things are composed; it consists of a nucleus in a mass of cytoplasm, which is usually enclosed within a cell wall (p. 34*).

***cell division:** the dividing of a cell into two similar daughter cells (p. 551,* *Amoeba*).

***cell wall:** the outer layer of cytoplasm of an animal or plant cell; in a plant cell it usually contains cellulose (p. 34*).

***cellulose** (sĕl′ū lōs): the material of which plant cell walls are chiefly composed (p. 34).

cephalothorax (sĕf ȧ lō thō′răx), or **head-thorax:** the combined head and thorax, as in Crustacea (p. 191).

***cerebellum** (sĕr ē bĕl′ŭm): the part of the brain which co-ordinates movements, that is, makes the movements occur together and in harmony (p. 427*).

***cerebrum** (sĕr′ē brŭm): the large part of the brain, occupying the upper part of the skull, controlling voluntary movement, or movement directed by the will, and, in man, the thought processes (p. 427*).

character (kăr'ăk tẽr): in its biological use a character is a characteristic, that is, one of the principal features or qualities of a living thing, as the color, size, form, or structure of its parts (p. 591).

chemical (kĕm'ĭ kăl) **change:** a change in which a substance is made into a new substance or new substances (p. 43).

***chlorophyll** (klō'rō fĭl): the green coloring matter of plants (p. 70).

***chloroplast** (klō'rō plăst): a structure in a plant cell which contains chlorophyll (p. 80*).

Chordata (kôr dā'tȧ): the phylum which includes all the chordates (kôr'dāts), or animals with a spinal cord (p. 207).

chromatin (krō'mȧ tĭn): the essential substance of chromosomes and nuclei; so called because it is readily seen in color when dyes are applied to the cells (p. 600).

chromosomes (krō'mō sōmz): bands or rods made from the chromatin; the chief structures involved in mitosis; the carriers of hereditary characters (p. 599*).

chrysalis (krĭs'ȧ lĭs): the dormant form of certain insects, in which the pupa is enclosed in a thin hard shell; corresponds to the cocoon in certain other insects (p. 198).

***cilia** (sĭl'ĭ ȧ), *singular* **cilium:** hair-like projections of protoplasm from the surface of a cell, which by their movements cause the cell to move or produce movement in the surrounding liquid (p. 150* (*Paramecium*) and p. 151).

***circulation** (sûr kū lā'shŭn): the process by which liquids and gases move from one place to another (p. 376).

circulatory (sûr'kū lă tō rĭ) **system:** the system of vessels by means of which blood or sap is carried through all parts of the body of all animals or plants (p. 360* and colored plate facing page 372).

classification (klăs ĭ fĭ kā'shŭn): a scheme by which plants and animals are put into related groups and are identified by their structures (p. 120).

clitellum (klĭ tĕl'ŭm): a thick gland-like region of the body of annelids, in which the cocoon is produced (p. 175*).

cloaca (klō ā'kȧ): the tube, in such chordates as the frog and the bird, through which digestive wastes, urinary wastes, and reproductive cells pass from the body (p. 217*).

coccus (kŏk'ŭs), *plural* **cocci** (kŏk'sī): a bacterium of the one of the three types of bacteria which has the shape of a ball (p. 132*).

cocoon (kŏ ko͞on'): the silken case which is spun by certain insect larvae and in which the pupa develops; a somewhat similar case is made by spiders and earthworms to enclose the eggs (p. 649*).

Coelenterata (sē lĕn tẽr ā'tȧ): the phylum of animals which contains the corals, sea anemones, jellyfish, and fresh-water hydras (pp. 158* and 159*).

***cold-blooded animal:** an animal having a body temperature that varies with that of its environment; examples are fish, amphibians, and reptiles (p. 388).

***communicable** (kŏ mū'nĭ kȧ bl) **disease:** a disease that may be transmitted from one person to another (p. 472).

complete flower: one having all parts, as petals, sepals, stamens, and pistil (p. 566).

Compositae (kŏm pŏz'ĭ tē): the most complex group of flowering plants, such as the dandelion, the sunflower, and the chrysanthemum (p. 146).

compound (kŏm'pound): a substance made by combining two or more elements (p. 39*).

***compound eye:** an eye composed of many small similar parts, or facets, as in insects and crustaceans (p. 466*).

conifers (kō′nĭ fẽrz): the cone-bearing plants (p. 142).

conjugation (kŏn jo͞o gā′shŭn): the process of the uniting of similar gametes, or sex cells (p. 564*).

contractile vacuole (kŏn trăk′tĭl văk′ū ōl): a bubble-like reservoir in the protoplasm of a protozoan, in which waste products are collected before being expelled from the cell (p. 396*).

control: a control in an experiment is any part of the experiment that gives a basis for the comparison of results or for checking the accuracy of results (p. 71).

***corolla** (kō rŏl′ȧ): one of the outer groups of specialized parts of a flower, usually colored; all the petals together (p. 55*).

***corpuscles** (kôr′pŭs lz): small bodies, such as the cells in the blood (p. 372).

cortex (kôr′tĕx): the outer protecting layers of roots and stems; also the outer layers of such organs as the brain and kidney; bark (pp. 97* and 102*).

***cotyledon** (kôt ĭ lē′dŭn): one of the seed leaves of a plant embryo (p. 143*).

***cranial** (krā′nĭ ăl): having to do with the skull, or cranium (p. 236*).

Crustacea (krŭs tā′shē ȧ), or **crustaceans** (krŭs tā′shē ănz): the class of arthropods which includes crayfish and lobsters (p. 186).

culture (kŭl′tu̱r): the cultivation of microscopic living things, such as bacteria, yeasts, and Protozoa (p. 131, Experiment 25).

cycle (sī′kl): a series of stages or processes through which living things and substances pass and which are repeated endlessly (pp. 86* and 197).

cyst (sĭst): a group of cells or a small organism, usually dormant, enclosed within a firm wall (p. 166); the hard covering of a dormant cell or group of cells (p. 151).

cytoplasm (sī′tō plăzm): all the protoplasm within a cell except the nucleus (p. 34*).

***decay** (dē kā′): to rot; to become broken up into simpler substances through the action of such plants as bacteria and molds (p. 249).

deciduous (dē sĭd′ū ŭs): falling off, as the leaves, at maturity, of certain trees, or the first teeth of human beings, or the antlers of deer (p. 77*).

***diaphragm** (dī′*a* frăm): the dome-like sheet of muscle separating the lung cavity from the abdominal cavity in mammals; used in breathing (p. 392*).

diastase (dī′ȧ stās): an enzyme which exists in germinating seeds, and which changes starch into sugar (p. 339).

***dicotyledon** (dī kŏt ĭ lē′dŭn), or **dicot** (dī′kŏt), or **dicotyl** (dī′kŏt ĭl): a plant having two seed leaves and belonging to one of the two divisions of the angiosperms (p. 143*).

***diffusion** (dĭ fū′zhŭn): the process by which molecules of liquids or gases or both mingle by their own movements (p. 43).

***digestion** (dĭ jĕs′chŭn): the processes by which foods are changed to certain liquids, which can then be absorbed and used by living cells (p. 336).

***digestive** (dĭ jĕs′tĭv): pertaining to digestion (p. 350).

dinosaur (dī′nō sôr): one of the group of extinct reptiles that lived millions of years ago (p. 218).

***disease, infectious** (ĭn fĕk′shŭs): a communicable disease caused by an organism carried from one plant or animal to another by contact with the diseased organism or with something it has touched (p. 476).

***disease germ** (dĭ zēz′ jûrm): any small organism that causes disease (p. 472).

division of labor: the performing of different kinds of work or functions by the special parts of a plant or animal (p. 55).

***dominant** (dŏm ĭ nănt): having power over another; having to do with transmitted characters (p. 603).

dormant (dôr′mănt): inactive or resting for a long period, as through a winter (p. 76).

__dorsal__ (dôr′săl): having to do with the back (p. 209).

Echinodermata (ē kī nō dûr′m*ȧ* t*ȧ*), or **echinoderms** (ē kī′nō dûrmz): the phylum of animals having spiny and hard coverings which usually are shell-like; examples are starfish and sea urchins (p. 172*).

ectoderm (ĕk′tō dûrm): the outer layer of cells in an early stage of the embryo of an animal or in a simple animal, as *Hydra* (p. 162).

__element__ (ĕl′ē mĕnt): a simple substance that cannot be broken up into simpler substances (p. 39).

elimination (ē lĭm ĭ nā′shŭn): the process of the removal of waste substances from an organism (p. 394).

__embryo__ (ĕm′brĭ ō): a plant or animal in its earliest stages of development (p. 573).

encyst (ĕn sĭst′): to enclose within a wall of tissue, as in a cyst (p. 305*).

endocrine (ĕn′dō krīn) **glands:** ductless glands; they secrete hormones directly into the blood (p. 402).

endoderm (ĕn′dō dûrm): the inner layer of cells in an early stage of the embryo of an animal or in a simple animal, as *Hydra* (p. 162).

endosperm (ĕn′dō spûrm): special food-storage tissue within certain plant seeds (p. 143*).

enemy (ĕn′ē mĭ): any organism or any condition that injures or kills a plant or an animal or otherwise makes its continued living difficult or impossible (p. 58).

__energy__ (ĕn′ẽr jĭ): the capacity to do work, that is, to move or to cause something else to move (p. 48).

energy cycle: the changing of energy from one form to another in endless succession without loss (p. 52*).

entomologist (ĕn tō mŏl′ō jĭst): a scientist who makes a special study of insects (p. 5).

*__environment__ (ĕn vī′rŭn mĕnt): the surroundings; all the factors within the habitat (p. 596).

*__enzyme__ (ĕn′zīm): an organic substance which causes such chemical changes as those of digestion or fermentation, without itself changing (p. 336).

__epidermis__ (ĕp ĭ dûr′mĭs): the outside tissue which covers the bodies of plants and animals, as the skin (p. 400).

epiglottis (ĕp ĭ glŏt′ĭs): the flap-like tissue which closes the windpipe when anything is swallowed (p. 389*).

epithelial (ĕp ĭ thē′lĭ ăl): having to do with the epithelium, or outer layer of tissue, as skin (p. 35).

*__esophagus__ (ē sŏf′*ȧ* gŭs), or **gullet** (gŭl′ĕt): the portion of the alimentary canal leading from the throat to the stomach (p. 344*).

Eustachian (ū stā′kĭ ăn) **tube:** the tube which leads from the middle ear to the throat (p. 460*).

evergreen (ĕv′ẽr grēn): one of the group of plants having, usually, needle-like leaves which remain green throughout the year (p. 77*).

excreta (ĕx krē′t*ȧ*): waste materials discharged from the intestines (p. 475).

*__excretion__ (ĕx krē′shŭn): the process of getting rid of the wastes which result from the use of food by living cells (p. 394).

*__exoskeleton__ (ĕx ō skĕl′ē tŭn): the hard outside covering of such animals as insects and crustaceans (p. 186).

experimental factor: in an experiment, the one condition which is varied (p. 71).

exterminate (ĕx tẽr′mĭ nāt): to kill all of any kind of plant or animal (p. 62).

extinct (ĕx tĭnkt′): no longer to be found living on the earth (p. 6*).

***fat:** one of the three groups of energy foods (p. 319).

feces (fē′sēz): the intestinal wastes of animals; the excrement (p. 169).

***fermentation** (fûr mĕn tā′shŭn): the process by which yeasts and bacteria act upon foods containing sugar to produce alcohol and carbon dioxide (p. 133).

***fertilization** (fûr tĭl ĭ zā′shŭn): the process in reproduction by which the sperm unites with the egg (p. 571).

fibrinogen (fī brĭn′ō jĕn): the material within the blood which when exposed to air forms the thread-like fibers of the clot (p. 374).

fibrovascular (fī brō văs′kū lẽr) **bundle, or vascular bundle:** a continuous structure extending from the roots, through the stem, and through the leaves (as veins) of plants. It is made up of long cells which function in transporting liquids (pp. 97* and 107*).

filament (fĭl′*ȧ* mĕnt): a fine thread (p. 127*); the part of the stamen that supports the anther (p. 55*).

filtrable virus (fĭl′tr*ȧ* bl vī′rŭs): a disease-producing organism or its products so small as to pass through laboratory filters (p. 471).

***fin:** a wing-like appendage extending from the body of a fish (p. 209*).

***fish:** the simplest vertebrate, breathing by means of gills and usually covered with scales (p. 209*).

fission (fĭsh′ŭn): the process of asexual reproduction by which a cell divides into two equal parts (p. 551*).

flagella (fl*ȧ* jĕl′*ȧ*), *singular* **flagellum:** hair-like extensions of protoplasm similar to cilia but usually longer and less numerous (p. 154).

***flower:** the part of a seed-bearing plant that contains the reproductive organs (p. 55*).

***food:** any substance which furnishes the body with material for growth or proper development (p. 315).

fossil (fŏs′ĭl): the preserved form or other evidence of an animal or plant that lived ages ago (p. 617*).

***fruit:** the ripened ovary and its contents and sometimes other structures that ripen with it (p. 568).

***function** (fŭngk′shŭn): use, or purpose (p. 55).

***fungus** (fŭng′gŭs), *plural* **fungi** (fŭn′jī): the group name for simple plants that do not have chlorophyll (p. 131).

gall bladder: the sac, or bag-like structure, in which bile from the liver is stored (p. 349*).

gametes (găm′ēts): the sex cells, which may unite to form a new individual (p. 565).

gametophyte (g*ȧ* mē′tō fīt): the sexual stage in the alternation of generations of plants (p. 579).

ganglion (găng′glĭ ŭn): a mass, or group, of nerve cells (p. 429*).

***gastric** (găs′trĭk): pertaining to the stomach, as gastric juice (p. 346).

gastrula (găs′trŏŏ l*ȧ*): the stage in the development of an animal embryo in which a portion of the wall is folded inward, giving the animal a cup-like shape (p. 577*).

generalization: in scientific work, a statement which summarizes many observations; a scientific principle is a generalization (p. 10).

genes (jēnz): the elements, or units, in the chromosomes of cells; each one is supposed to be responsible for carrying certain hereditary characters (p. 599).

genus (jē′nŭs), *plural* **genera** (jĕn′ẽr *ȧ*): a group which usually includes several species; the group next smaller than a family (p. 120).

geotropism (jē ŏt′rō pĭzm): tendency of organs, as roots, to be attracted toward the earth (p. 418, footnote).

***germ** (jûrm): a plant or an animal that causes disease (p. 472).

germicide (jûr′mĭ sīd): a substance that kills germs, as tincture of iodine (p. 473).

***germination** (jûr mĭ nā′shŭn): the process by which a young plant bursts through its seed coat and continues its development (p. 415, Experiment 55).

***gill** (gĭl): a structure found in aquatic animals, adapted for securing oxygen from the water (pp. 190* and 385*).

gizzard (gĭz′ẽrd): a muscular digestive organ which grinds up the food of birds and of some lower animals (p. 227*).

***gland:** a group of cells which secrete some substance, as saliva or oil (p. 403).

glycogen (glī′kō jĕn): a form of carbohydrate known as animal starch, stored chiefly in the liver (p. 319).

***grafting:** the process of inserting a branch, scion, or piece in another organism so as to make it grow as part of that organism (p. 557*).

***growth:** the increase in size of plant or animal bodies (p. 100).

***guard cells:** the cells in the epidermis of a leaf which regulate the size of a stoma (p. 80*).

***gullet** (gŭl′ĕt), or **esophagus** (ē sŏf′*a* gŭs): the portion of the alimentary canal which leads from the throat to the stomach (p. 344*).

gymnosperms (jĭm′nō spûrmz): the group of seed plants of which the ovules are exposed, as pines and firs (p. 142).

***habit:** an action which has been repeated so many times that it is done without thinking; a characteristic or tendency (p. 438).

***habitat** (hăb′ĭ tăt): the region in which a plant or an animal lives (p. 18*).

***heart:** an organ which causes blood to circulate through the blood vessels (pp. 367 and 392*).

heliotropism (hē lĭ ŏt′rō pĭzm): the tendency of green plants to grow toward the sunlight (pp. 72, Experiment 8, and 418, footnote).

hemoglobin (hē mō glō′bĭn): the iron compound in the red blood corpuscles, which carries oxygen and carbon dioxide (p. 373).

hereditary (hē rĕd′ĭ tĕr ĭ): transmitted from parents to their offspring (p. 612).

***heredity** (hē rĕd′ĭ tĭ): having to do with inherited, or transmitted, characters (p. 540).

hermaphrodite (hûr măf′rō dīt): an animal possessing both male and female sex organs (p. 570).

hermaphroditic (hûr măf rō dĭt′ĭk): possessing both male and female reproductive structures (p. 570).

hibernate (hī′bẽr nāt): to pass the winter in a dormant condition (p. 198).

homologous (hō mŏl′ō gŭs): similar in structure or in location on the body (pp. 210 and 234*).

hormone (hôr′mōn): the chemical product of a ductless gland which affects the development or functioning of some other part of the body (p. 403).

***host:** the organism on or in which a parasite lives (p. 167*).

humus (hū′mŭs): organic matter in the soil resulting from decay (p. 247).

hybrid (hī′brĭd): the offspring of two parents which are considerably unlike in some of their hereditary characters (p. 606* and legend).

***hydrogen** (hī′drō jĕn): an element that is a colorless, odorless gas; it is one of the elements found in water and in all organic compounds (p. 39).

hydrotropism (hī drŏt′rō pĭzm): the tendency of organs to be attracted toward water (p. 418, footnote).

hygiene (hī′jēn): the branch of science that deals with the conditions affecting health for the purpose of promoting its improvement (p. 510).

hypocotyl (hī pō kŏt′ĭl): the part of an embryo plant below the seed leaves, most of which develops into the root (p. 143*).

hypothesis (hī pŏth'ē sĭs): something which is assumed, or taken for granted, as a basis for reasoning; an explanation which is invented to explain all known facts related to some problem, or an attempt to predict what will happen under certain conditions (p. 10).

imbibition (ĭm bĭ bĭsh'ŭn): the passage of water into dead cells and into the microscopic pores and spaces in cell walls (p. 90).

immunity (ĭ mū'nĭ tĭ): the condition in which an organism is able to resist the attacks of disease (p. 482).

incubation (ĭn kū bā'shŭn): the process of maintaining proper conditions of heat and moisture for developing animals within the egg covering (p. 576).

***infection** (ĭn fĕk'shŭn): a disease that is caused by germs carried from one plant or animal to another; the state of being infected; the act of infecting (p. 479).

inference (ĭn'fēr ĕns): a process of reasoning and forming conclusions; a conclusion arrived at by reasoning (p. 26,* legend).

infest (ĭn fĕst'): to enter or take possession in such numbers as to threaten the life or welfare of other organisms (p. 169).

infusion (ĭn fū'zhŭn): a nourishing liquid, made by steeping organic material in water, in which microscopic organisms are grown (p. 545).

inheritance (ĭn hĕr'ĭ tăns): the reception of characteristics from ancestors (p. 611).

inoculation (ĭn ŏk ū lā'shŭn): act of infecting with microscopic forms (p. 485).

***inorganic matter:** matter which is not, and has never been, either a living thing or the product of any living thing (p. 40).

Insecta (ĭn sĕk'tȧ), or **insects:** the class of arthropods of which the members have six legs, wings (usually), and spiracles for breathing (p. 186).

instinct (ĭn'stĭngkt): a complex unlearned reaction, as nest-building (p. 424).

insulin (ĭn'sū lĭn): a hormone secreted by certain cells in the pancreas; a remedy, containing this hormone, used in the treatment of diabetes (p. 407).

intestine (ĭn tĕs'tĭn): the part of the food canal following the stomach (p. 344*).

***invertebrate** (ĭn vûr'tē brāt): an animal that does not possess an internal skeleton (p. 205,* first nine animals).

involuntary (ĭn vŏl'ŭn tĕr ĭ): not directed by the will or not under the control of the will (p. 424).

***irritability** (ĭr ĭ tȧ bĭl'ĭ tĭ): the capacity for responding, or reacting, to stimuli (p. 414).

***kidney** (kĭd'nĭ): a highly specialized organ of excretion which removes waste products, chiefly water and urea, from the blood (p. 399).

***lacteals** (lăk'tē ălz): the lymphatic vessels in the villi, into which digested fats pass (p. 375*).

***large** intestine: the division of the alimentary canal which follows the small intestine and in which the waste materials are stored before evacuation (pp. 344* and 353).

***larva** (lär'vȧ), *plural* **larvae** (lär'vē): the worm-like stage of certain insects (colored illustration, facing page 196).

***larynx** (lăr'ĭngks): the voice box; the box-like upper part of the windpipe, containing the vocal cords (p. 391*).

***leaf:** a plant part which is usually broad, flat, and green (p. 144*).

legume (lĕg'ūm): one of the plants having irregular flowers and bearing pods, as pea and alfalfa (p. 249).

***lens:** a transparent curved structure in the eye, which focuses the light rays (p. 459*).

lenticel (lĕn'tĭ sĕl): a small opening in bark, through which gases may pass (p. 101*).

lichen (lī'kĕn): a plant which is composed of fungi and algae living in partnership (p. 137*).

life cycle: all the different stages of development through which an organism passes; life history (pp. 166* and 214*).

lipase (lī′pās): the enzyme which digests fats (p. 348).

***liver** (lĭv′ẽr): the largest gland; it secretes bile, stores glycogen, and produces important changes in the blood (pp. 349* and 399).

liverworts (lĭv′ẽr wûrts): green plants, usually flat, which, with the mosses, compose the phylum Bryophyta (pp. 138 and 139*).

***lizard** (lĭz′ẽrd): a reptile having a scale-covered body, a long tail, movable eyelids, and usually legs (pp. 222 and 224*).

***locomotion** (lō kō mō′shŭn): act of moving from place to place (p. 56).

***lymph** (lĭmf): the fluid which surrounds the cells; it is composed of plasma which has escaped from the capillaries (p. 370).

lymphatic (lĭm făt′ĭk): a tube which carries lymph (p. 370*).

lymphatic system: all the lymph glands and the vessels through which lymph passes on its way back into the circulatory system (pp. 369 and 370*).

Malpighian (măl pĭg′ĭ ăn) **tubes:** excretory organs of insects which remove waste products, chiefly water and urea, from the blood and discharge them into the intestine (p. 397).

mammal (măm′ăl): one of the highest group of chordates, the Mammalia (mă mā′lĭ *ȧ*), which feeds its young on milk secreted by milk glands, or mammary (măm′*ȧ* rĭ) glands (p. 233*).

mandibles (măn′dĭ blz): the biting mouth parts of insects or crustaceans (p. 195*).

marsupials (mär sū′pĭ ălz): mammals having a pouch for their young (p. 232).

matter cycle: the passing of matter from one living thing to another in endless succession (p. 52*).

maxilliped (măx ĭl′ĭ pĕd): one of the leg-like mouth parts of crustaceans (p. 191*).

medulla (mē dŭl′*ȧ*): the posterior region of the brain, which controls such involuntary movements as those of breathing and the beating of the heart (p. 427).

medullary (mĕd′ŭ lĕr ĭ) **ray, or pith ray:** a group of tissues radiating, or running outward in all directions, from the center toward the outside of a stem, which carry water and food horizontally to cells not directly served by xylem and phloem (p. 102*).

***membrane** (mĕm′brān): a thin sheet of tissue (p. 345).

mesentery (mĕs′ĕn tĕr ĭ): the membranes which surround the intestines and support them from the dorsal walls of the abdomen (p. 217*).

metabolism (mĕ tăb′ō lĭzm): the processes related to building up (anabolism) and breaking down (catabolism) the living parts of plants and animals (p. 314).

***metamorphosis** (mĕt *ȧ* môr′fō sĭs): the changes in form which an animal undergoes in developing to the adult stage (colored illustration facing page 196; p. 214*).

Metazoa (mĕt *ȧ* zō′*ȧ*): the group which includes all animals consisting of more than one cell (pp. 154 and 205* (all but the first animal)).

***microscope** (mī′krō skōp): an instrument which enlarges, or magnifies, the view of small objects so that they can be seen and studied (p. 33*).

***microscopic** (mī krō skŏp′ĭk): so small as to be invisible without the aid of a microscope (p. 127*).

midrib (mĭd′rĭb): the central vein of a leaf (p. 79*).

***migration** (mī grā′shŭn): the act of moving from one region to another (p. 581).

mitosis (mĭ tō′sĭs): the entire process of cell division through formation of chromosomes, their division, and the formation of new cells (pp. 600 and 601*).

mixture (mĭx't͜ūr): two or more substances which exist together without combining to form a new substance (p. 39*).

molds: a group of small fungus plants (p. 134*).

Mollusca (mŏ lŭs'kȧ), or **mollusks** (mŏl'lŭsks): the phylum of animals which have soft bodies, usually enclosed in a shell, and a foot for digging or for locomotion (p. 177*).

molt: to shed feathers, skin, or other covering (p. 193), (p. 197*).

monocotyledon (mŏn ō kŏt ĭ lē'dŭn), or **monocot** (mŏn'ō kŏt), or **monocotyl** (mŏn'ō kŏt ĭl): a plant with one seed leaf, belonging to one of the two divisions of the angiosperms (p. 143*).

***mucous membrane** (mū'kŭs mĕm'brān): the moist lining of those tubes, or canals, which open to the outside of the body (p. 345).

***mucus** (mū'kŭs): a substance, secreted by small glands, which makes slippery the walls of the digestive and respiratory systems; the slippery substance secreted by the skin of some animals, as fish (p. 345).

***muscle:** a group of cells which by contracting cause bodily movement (p. 522).

mutant (mū'tănt): a plant or animal which possesses and transmits to its offspring any distinctly changed character (p. 594).

mutation (mū tā'shŭn): a modification of a distinct character, which can be inherited (p. 594).

Myriapoda (mĭr ĭ ăp'ō dȧ), or **myriapods** (mĭr'ĭ ȧ pŏdz): the class of arthropods distinguished by many pairs of legs (p. 188).

narcotic (när kŏt'ĭk): any substance which dulls the senses or produces sleep (p. 534).

natural immunity (ĭ mū'nĭ tĭ): the ability to resist a disease because of inherited characters, general health, or age (p. 482).

Nemathelminthes (nĕm ȧ thĕl mĭn'thēz), or **nemathelminths** (nĕm ȧ thĕl'mĭnths): roundworms, the major group of animals, mostly parasites, having round bodies (p. 168).

***nerve:** a bundle of nerve fibers (p. 420).

***net-veined leaf:** a leaf with many small veins which form a net-work throughout the leaf (p. 79*).

neuron (nū'rŏn): a nerve cell (p. 419).

nictitating (nĭk'tĭ tā tĭng) **membrane:** the third eyelid of certain animals, as frogs, birds, and turtles; also present but incomplete in some of the higher vertebrates (p. 215, Experiment 38).

***nitrogen** (nī'trō jĕn): the colorless, odorless gas which composes about 78 per cent of the air; an element always present in protein and in protoplasm (p. 40).

***nitrogen-fixing bacteria:** bacteria growing on the roots of legumes (pod-bearing plants) and having the ability to combine the nitrogen of the air with other substances to form nitrogen compounds (p. 249).

non-energy foods: all foods except carbohydrates, proteins, and fats (p. 314).

notochord (nō'tō kôrd): the rod of cartilage which supports the nerve cord in the lowest chordates (p. 206).

***nucleus** (nū'klē ŭs): the small, dense mass of protoplasm within a cell which controls cell activities and cell division; it contains the bodies which transmit hereditary characters (p. 34*).

***nutrient** (nū'trĭ ĕnt): serving as food; anything which nourishes living things (p. 317).

nutrition (nū trĭsh'ŭn): all the processes concerned with the utilization of food by living organisms (p. 29).

nymph (nĭmf): the immature form of an insect that undergoes an incomplete metamorphosis (p. 198*).

olfactory (ŏl făk'tō rĭ): pertaining to the sense of smell (p. 425).

omnivorous (ŏm nĭv'ō rŭs): feeding on both plants and animals (p. 312).

operculum (ō pûr'kū lŭm), or **gill cover:** a fold or plate of tissue such as that covering the gills of a fish or a young tadpole; the covering or lid of a spore case (p. 209*).

optic (ŏp'tĭk): pertaining to the sense of sight (p. 425).

***organ** (ôr'găn): a group of tissues which together perform some special function (p. 34).

***organic** (ôr găn'ĭk): pertaining to an animal or plant (p. 41).

***organic matter:** matter which is a part or a product of an organism (p. 41).

***organism** (ôr'găn ĭzm): any living thing (p. 41).

***osmosis** (ŏs mō'sĭs): the passing of liquids or gases through moist cell walls or other membranes from places of higher concentration of a substance to those of lower concentration of it (p. 44).

osmotic (ŏs mŏt'ĭk) **pressure:** the pressure which is caused by the unequal concentration of solutions separated by a membrane, and which results in osmosis (p. 44).

***ovary** (ō'vȧ rĭ): in plants, the part of the pistil within which ovules are formed; in animals, the organ in which eggs are formed (p. 55*).

ovipositor (ō'vĭ pŏz'ĭ tẽr): the egg-laying organ which enables certain insects, as the grasshopper and the ichneumon fly, to pierce such substances as bark, earth, or epidermis to deposit eggs (p. 195*).

ovule (ō'vūl): the structure within the ovary of a plant in which the embryo develops (p. 55*).

***oxidation** (ŏx ĭ dā'shŭn): the process in which oxygen combines with another substance, releasing energy, usually in the form of heat and movement (p. 42).

***oxygen** (ŏx'ĭ jĕn): the colorless, odorless element composing about 20 per cent of the air; it is essential to all plants and animals in order that oxidation of food may occur, thus releasing energy (p. 16).

palisade (păl ĭ sād') **tissue:** long green cells in a leaf arranged in parallel rows, usually beneath the upper epidermis (p. 80*).

***pancreas** (păn'krē ăs): a highly specialized gland which produces several digestive enzymes and the hormone insulin (pp. 349* and 407).

***Paramecium** (păr ȧ mē'shĭ ŭm): a genus of one-celled slipper-shaped animals (p. 150*).

***parasite** (păr'ȧ sīt): an animal or plant which lives on or within another living plant or animal and secures its nourishment at the expense of this other organism, or host (p. 53*).

***parasitic** (păr ȧ sĭt'ĭk): living as a parasite (p. 475).

pelvis (pĕl'vĭs): the frame-work of bone which supports the abdominal organs of many of the vertebrates (p. 236*).

perfect flower: a flower which has stamens and one or more pistils but which may lack petals and sepals (p. 566*).

pericardium (pĕr ĭ kär'dĭ ŭm): the membrane surrounding the heart (p. 366).

periosteum (pĕr ĭ ŏs'tē ŭm): the outer tissue of the bone (p. 237*).

***perspiration** (pûr spĭ rā'shŭn): sweat, or the fluid produced by certain glands in the skin (p. 400).

***petal** (pĕt'l): one of the row of flower parts, usually colored, which surrounds the stamens (p. 55*).

petiole (pĕt'ĭ ōl): the stalk of a leaf, which attaches it to the stem (p. 79*).

***pharynx** (făr'ĭngx): the cavity, or passage, between the nose and the windpipe (p. 389*).

phloem (flō'ĕm): the outer region of the vascular bundle through which sap descends (p. 97*).

***photosynthesis** (fō tō sĭn′thē sĭs): the process by which chlorophyll, using the sun's energy, manufactures carbohydrates from carbon dioxide and water, and releases oxygen (p. 85).

phototropism (fō tŏt′rō pĭzm): the tendency of plants and animals to respond to light (p. 418 footnote).

phylum (fī′lŭm), *plural* **phyla** (fī′lȧ): one of the major divisions of the plant or the animal kingdom (p. 122).

***physiology** (fĭz ĭ ŏl′ō jĭ): the branch of science that includes the study of the living processes of plants and animals (p. 5).

Pisces (pĭs′ēz): the class of chordates which includes all the fishes (p. 207).

***pistil** (pĭs′tĭl): the central part of a flower, consisting of ovary, style, and stigma (p. 55*).

pistillate (pĭs′tĭl āt): having pistils but no stamens (p. 568*).

***pith:** the spongy tissue in stems and branches, usually composed of large thin-walled cells (p. 97*).

pith ray, or medullary (mĕd′ŭ lĕr ĭ) **ray:** a tissue extending outward in all directions from the center toward the outside of a stem and carrying water and food horizontally to cells not served directly by xylem and phloem (p. 102*).

placenta (plȧ sĕn′tȧ): the vascular tissue (tissue through which blood or sap flows) which attaches a developing embryo to the parent, and through which the embryo secures food and oxygen (p. 573*).

plasma (plăz′mȧ): the liquid part of the blood (p. 372).

Platyhelminthes (plăt ĭ hĕl mĭn′thēz), or **platyhelminths** (plăt ĭ hĕl′mĭnths): flatworms, the phylum of animals having soft, thin, flat bodies (pp. 164* and 166*).

pleura (plo͞or′ȧ): the bag-like membrane which encloses the lungs (p. 391).

plumule (plo͞o′mūl): the leaves and stem of an embryo plant (p. 143*).

***pollen** (pŏl′ĕn): small asexual spores of plants, from which the male cells may develop (p. 567*).

***pollen tube:** the tube which develops from a pollen grain when it germinates, and through which male gametes travel during the process of fertilization (p. 567*).

***pollination** (pŏl ĭ nā′shŭn): the transfer of pollen from the stamen to the stigma (p. 569*).

Porifera (pō rĭf′ẽr ȧ): the phylum of porous animals, which includes the sponges (p. 155*).

***posterior** (pŏs tēr′ĭ ẽr): toward the rear, as opposed to the head, of an animal (p. 191, Experiment 35).

primate (prī′mĭt): an individual member of the class Primates (p. 234).

Primates (prī mā′tēz): the highest class of chordates, that to which man belongs (p. 234).

propagation (prŏp ȧ gā′shŭn): the act of reproducing, of multiplying, or of increasing in numbers (p. 179).

protective (prō tĕk′tĭv) **coloration:** body colors of an animal which blend with the surroundings, with the result that the animal is hard to see (p. 60*).

protective resemblance: such a similarity to other objects in color, form, or habit as assists an animal to survive (pp. 60* and 199*).

***protein** (prō′tē ĭn): a complex energy food containing nitrogen, carbon, hydrogen, oxygen, and other elements (p. 320).

***protoplasm** (prō′tō plăzm): the living substance of the cell (p. 29).

***Protozoa** (prō tō zō′ȧ): the phylum which includes the one-celled animals (p. 151*).

Pteridophyta (tĕr ĭ dŏf′ĭ tȧ): the phylum of plants which includes the ferns, club mosses, and horsetails (pp. 140* and 141*).

pulmonary (pŭl′mō nĕr ĭ): having to do with the lungs (p. 367*).

***pulse:** the throbbing, or beating, in an artery, as blood is forced through it (p. 369, Experiment 51).

***pupil:** the opening in the iris through which light enters the eye (p. 458).

quarantine (kwŏr′ăn tēn): a period during which plants, animals, or people having or suspected of having an infectious disease are kept away from others until danger of spread of the disease has passed (p. 481).

radial symmetry (rā′dĭ ăl sĭm′ē trĭ): the arrangement of structures of an organism by which the major parts radiate, or extend outward in all directions, from the center, as in the starfish or in the leaves of a moss plant (p. 159).

recessive (rē sĕs′ĭv) **character:** a character which does not appear in offspring, because it is obscured by a dominant character, but which can be transmitted to a later generation (p. 603).

reflex (rē′flĕx) **actions:** bodily actions controlled by spinal nerve centers without conscious direction from the brain (p. 420).

reflex arc: all the sensory and motor nerves involved in producing a reflex action (p. 428*).

regeneration (rē jĕn ẽr ā′shŭn): the replacing of an injured or missing part or parts (p. 555*).

***reproduction** (rē prō dŭk′shŭn): the process of producing new living things (p. 548).

Reptilia (rĕp tĭl′ĭ *ȧ*) or **reptiles:** the class of chordates which includes snakes, lizards, and alligators (p. 219).

***respiration** (rĕs pĭ rā′shŭn): the process by which an organism takes in oxygen and gives off carbon dioxide (p. 380).

rhizoids (rī′zoidz): root-like outgrowths, as the hair-like growths at the lower ends of moss stems and on the under sides of some liverworts (p. 578).

***rodent** (rō′dĕnt): a mammal of the order Rodentia, characterized by having gnawing teeth (p. 232).

***root cap:** a group of cells which cover the growing tip of a root (p. 106*).

***root hair:** a fine hair-like growth from the epidermis of a small root (pp. 106* and 107*).

rudimentary (rōō dĭ mĕn′t*ȧ* rĭ): having ceased to develop while still in an immature stage (p. 359).

rusts: a group of parasitic fungi, some of which produce serious diseases in certain higher plants (pp. 265 and 266*).

sac (săk): a bag-like part of an organism, which often contains a fluid (p. 404*).

***saliva** (s*ȧ* lī′v*a*): a digestive secretion, produced by glands in the mouth, which changes starch to sugar (p. 343).

saprophyte (săp′rō fīt): a plant which secures its nourishment from the dead and decaying bodies of other plants and animals (p. 135).

scion (sī′ŭn): a branch or cutting from which new growth may be produced (p. 558).

secrete (sē krēt′): to produce special liquids, as the liquids produced by glands (p. 404).

***secretion** (sē krē′shŭn): the process by which a gland produces a liquid substance, as a hormone or an enzyme; the product of a gland (p. 402).

***seed:** a plant structure which contains the embryo; the ripened and mature ovule (pp. 566 and 568).

***seedling** (sēd′lĭng): a young plant which has recently developed from a seed (p. 106*).

***segment** (sĕg′mĕnt): one of the ring-like divisions composing the body of such an animal as an annelid; arthropods and chordates are also segmented animals (p. 174, Experiment 33).

***self-pollination:** the transfer of pollen from a stamen to the stigma of the same flower (p. 569*).

semicircular canals: the canals in the bony part of the ear which constitute an organ of equilibrium, or balance (p. 460*).

***sensation** (sĕn sā′shŭn): any feeling or process within the body resulting from a stimulus (p. 428*).

***sense organ:** a specialized structure which responds to a certain kind of stimulus, as light, sound, taste, and the like (p. 451).

sensory neuron (nū′rŏn): a nerve fiber over which impulses are carried from a stimulated area toward the brain or spinal cord (p. 428).

***sepal** (sē′păl): one of the outer row of flower parts, usually green (p. 55*).

***serum** (sēr′ŭm): the clear yellow liquid which remains when blood clots (p. 375); a substance injected into the blood in the treatment or prevention of certain diseases (p. 494).

***sexual** (sĕk′sho͝o ăl): characterized by having male or female reproductive cells; having to do with sex (p. 570).

***sexual reproduction:** reproduction in which male and female sex cells unite to produce an embryo (p. 570).

***simple eye:** a small group of cells sensitive to light, found in insects and spiders (p. 457).

***skeleton** (skĕl′ē tŭn): the supporting or protecting structures of an organism (pp. 219* and 236*).

***small intestine:** the portion of the alimentary canal between the stomach and the large intestine, in which practically all digestion is completed (p. 344*).

soil: crumbled rock, usually mixed with decaying organic matter, or humus (p. 247).

***soluble** (sŏl′ū bl): capable of being dissolved (p. 247).

***species** (spē′shēz): a group of animals or plants having certain common characteristics which distinguish them from all others (p. 120).

***sperm:** one of the male reproductive cells of plants and animals (p. 565).

spermatophytes (spûr′mȧ tō fīts): plants of the phylum Spermatophyta, which includes all seed plants (p. 142).

***spinal column:** the backbone; the vertebral column (p. 205,* last five animals).

***spinal cord:** a nerve cord running lengthwise through the spinal column (p. 204).

spiracle (spī′rȧ kl): an opening into the body for breathing, as in insects and tadpoles (p. 195*).

spirillum (spī rĭl′ŭm), *plural* **spirilla** (spī-rĭl′ȧ): a bacterium of the one of the three types of bacteria that has a spiral shape (p. 132*).

spleen: an abdominal organ which is commonly thought to be a ductless gland but the function of which is not definitely known (p. 367*).

spongy tissue: loosely arranged chlorophyll cells of the leaf; the less compact tissues of the bones (p. 80*).

spontaneous generation (spŏn tā′nē ŭs jĕn-ēr ā′shŭn): the theory, now known to be without scientific support, that living things can be produced from non-living things (p. 542).

sporangium (spō răn′jĭ ŭm), *plural* **sporangia:** the cell or case in which asexual spores are produced (p. 579).

***spore:** an asexual reproductive cell capable of developing into the same kind of living thing that produced the spore (p. 580*).

sporophyte (spō′rō fīt): the asexual stage in the alternation of generations of plants (p. 579).

***stamen** (stā′mĕn): the part of a flower which bears the pollen (p. 55*).

staminate (stăm′ĭ nāt): pertaining to those flowers which possess stamens but not pistils (p. 568).

***stem:** the main stalk of a tree or other plant (p. 94).

sterilize (stĕr′ĭ līz): to destroy all germs within or upon a substance; to make reproduction impossible (p. 131, Experiment 25).

***stigma:** the tip of the pistil (p. 55*).

***stimulus** (stĭm′ū lŭs): that which produces or arouses action or response (p. 414).

stolon (stō′lŏn): a branch or runner from which new plants may develop (p. 554).

stoma (stō′mȧ), *plural* **stomata** (stō′mȧ tȧ): openings in leaves or stems through which gases enter and leave the plant (p. 80*).

***stomach** (stŭm′ăk): the bag-like portion of the alimentary canal, in which food is stored and partly digested (p. 344*).

***sugar:** a carbohydrate which results from photosynthesis and from the digestion of starch (p. 319).

***sweat gland:** a gland in the skin which excretes sweat, or perspiration (p. 400*).

swimmerets (swĭm′ẽr ĕts): appendages on the abdomen of a crustacean which aid in swimming, in reproduction, and, indirectly, in respiration (p. 191*).

symbiosis (sĭm bĭ ō′sĭs): a partnership of two or more totally different organisms, in which each contributes something to the welfare of the other or others (pp. 25* and 137*).

system of classification: the plan, or scheme, by which living things are grouped and named according to relationship in structure and habit (p. 123*).

***taproot:** a main root which grows directly downward (p. 105).

tendon (tĕn′dŭn): the tough cord or band which attaches a muscle to a bone (p. 216, Experiment 38).

tentacles (tĕn′tȧ klz): flexible appendages which may aid such animals as *Hydra* and the octopus in food-getting, in locomotion, or in various ways as sense organs (p. 159*).

testes (tĕs′tēz): male sex glands, in which sperms are produced (p. 570).

Thallophyta (thă lŏf′ĭ tȧ): the lowest phylum of plants, including the algae and fungi (p. 129).

***thorax** (thō′răx): the middle division of an insect's body, to which the legs are attached; in higher animals, the part of the body between the abdomen and the neck (p. 195*).

***thyroid** (thī′roid): an endocrine gland located in the neck (p. 405*).

tissue (tĭsh′ū): a group of cells of the same kind, serving the same function (p. 35*).

***tonsil** (tŏn′sĭl): a mass of tissue growing on either side of the pharynx (p. 389*).

***toxin** (tŏx′ĭn): a poisonous protein formed by disease-producing germs (p. 482).

***trachea** (trā′kē ȧ): in higher animals, the air passage leading from the throat to the lungs; in insects, one of the air tubes (pp. 386* and 390*).

***transpiration** (trăn spĭ rā′shŭn): the process of evaporating water into the air from plants (p. 88).

trichinosis (trĭk ĭ nō′sĭs): a disease produced by a small roundworm (p. 170*).

tropism (trō′pĭzm): the simplest reaction to a stimulus (p. 417).

tubercles (tū′bẽr klz): small rounded structures projecting from a surface, as the nodules on roots of clover, beans, etc., in which nitrogen-fixing bacteria grow (p. 249).

tympanic (tĭm păn′ĭk) **membrane:** the tightly stretched membrane which by vibrating produces the sensation of hearing; in higher animals, the ear-drum (p. 460*).

ungulates (ŭng′gū lāts): hoofed mammals (p. 232).

unit character: a character, or characteristic, or a structure which is inherited independently of other characters (p. 606).

urea (ū rē′ȧ): a waste product which contains nitrogen and which results from metabolism and is excreted in the urine of higher animals (p. 399).

urinary bladder: the bag-like organ in which urine is collected (pp. 399* and 400).

vaccination (văk sĭ nā'shŭn): the introduction into an animal of dead or weakened germs or their products, as a means of inducing immunity (p. 497).

vacuole (văk'ū ōl): an area in a cell filled with gas, with food in process of digestion, or with liquid excretions (p. 396*).

***variation** (vâr ĭ ā'shŭn): deviation in structure or function from the parent (p. 591).

***vascular** (văs'kū lẽr) **bundle, or fibrovascular** (fī brō văs'kū lẽr) **bundle:** a bundle of long cells which function in transporting liquids in plants (pp. 97* and 107*).

vascular system: any system of tubes used in transporting liquids, as blood or sap, in animals or plants (pp. 360* and colored plate facing page 372).

vegetative reproduction: production of new individuals directly from a growing, or vegetative, part of an organism (p. 554).

veins (vānz): the blood vessels through which blood returns to the heart (colored plate facing page 372); the vascular bundles in a leaf (p. 79*).

***ventral** (vĕn'trăl): pertaining to the lower, or abdominal, side of the body (p. 175*).

***ventricle** (vĕn'trĭ kl): the chamber of the heart from which the blood is forced into an artery (p. 366*).

***vertebra** (vûr'tē brȧ), *plural* **vertebrae** (vûr'tē brē): one of the segments of the backbone, or spinal column (p. 428*).

***vertebrate** (vûr'tē brāt): one of the group of chordates which has a spinal column of bones, serving as the main support of the body (p. 205,* the last five animals).

villi (vĭl'ī): small projections from the walls of the small intestine which serve to absorb food into the blood stream (p. 352*).

virus (vī'rŭs): a poison, produced by disease germs, which can be used to cause a disease in a plant or animal (p. 496). *See also* filtrable virus (p. 471).

vitamin (vī'*tȧ* mĭn): one of a group of non-energy foods necessary to health and normal development (p. 325).

voluntary (vŏl'ŭn tĕr ĭ): having to do with the will (p. 427).

***warm-blooded animal:** an animal with a constant body temperature, that is, a temperature that does not vary with the environment (p. 232).

***white corpuscle:** one of the types of blood cells (p. 374).

xylem (zī'lĕm): the inner region of a vascular bundle, containing hard, woody tissue and cells which transport liquids upward (p. 97*).

yeasts: a group of microscopic, one-celled fungus plants (p. 134*).

***zoology** (zō ŏl'ō jĭ): the science which is concerned with the study of animals (p. 5).

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